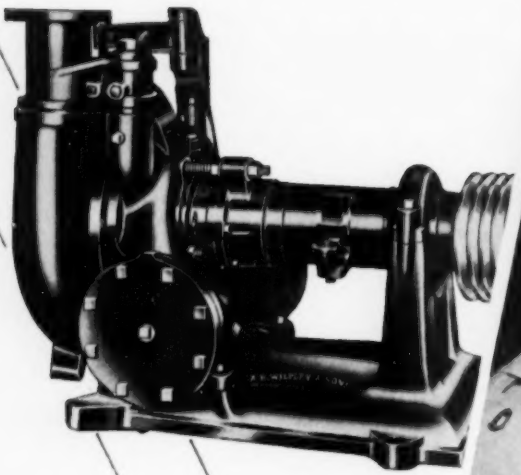
MINING engineering

JUNE 1953

SHERRITT GORDON'S NICKEL - COPPER - COBALT PROJECT



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VOL. 5 NO. 6 JUNE, 1953

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COVER

Sherritt Gordon Mines Ltd. reaches across half of Canada in the various aspects of its Nickel-Copper-Cobalt project. Sulphide concentrate from the mine at Lynn Lake in Northern Manitoba will be treated in a refinery and chemical plant now building in Saskatchewan, and the refining process was developed and piloted in laboratories at Ottawa.

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– Personnel Service –

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

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Safety Engineer, 33, married, children. Eleven years experience explosives, safety, handling, manufacturing, shipping, and storage; including inspection of manufacturing and loading plants of all types, preparation of reports and publications. B. S. Metallurgical Engineering. Some mine and mill experience. Desire to broaden experience in administration and plant operation. M-29.

Mining Engineer, 27, degrees in metallurgical engineering and geology; proven administrative ability. Experienced underground operations, milling and experimentation, surveying, mapping, sampling, assistant geologist, office procedure, plant maintenance, dredge operator. Fair Spanish and French. Desires position exploration, beneficiation or project engineering program, underground, open pit or placer. Foreign employment only. Available immediately. M-27.

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Engineers. (a) Superintendent for graphite mine in Mexico. Executive ability and fluent Spanish essential. Give training, experience and date available. Salary, commensurate with ability. (b) Mining Engineer titled and registered in accordance with Mexican law. Duties not limited to engineering. Excellent opportunity to gain operating experience. Location, Mexico. F-8573.

Economic Geologist, staff position, to do field work, investigate ore deposits and prepare geological reports. Well trained in fundamental geology and have ability in microscopic petrography and the study of polished surface. Some training or experience in mining helpful. Rank and salary open. Master's degree or better. Location, West. Y8570(b).

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MESH	**CUMULATIVE % PLUS THE MESH**		
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100	15.8	2.6	40.2
150	28.4	6.8	60.1
200	42.9	18.1	75.8
—200	57.1	81.9	24.2

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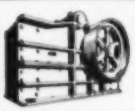
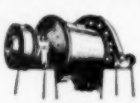

Jaw Crushers

Gyratory Crushers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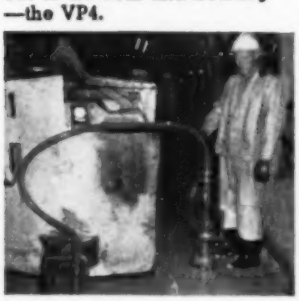

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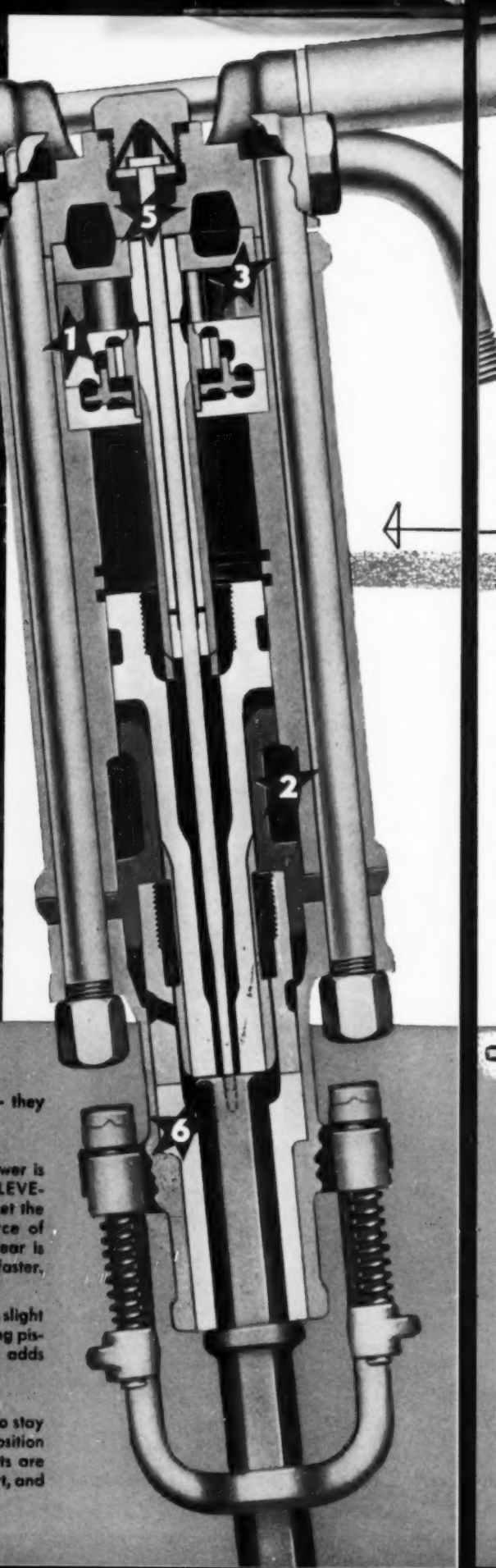

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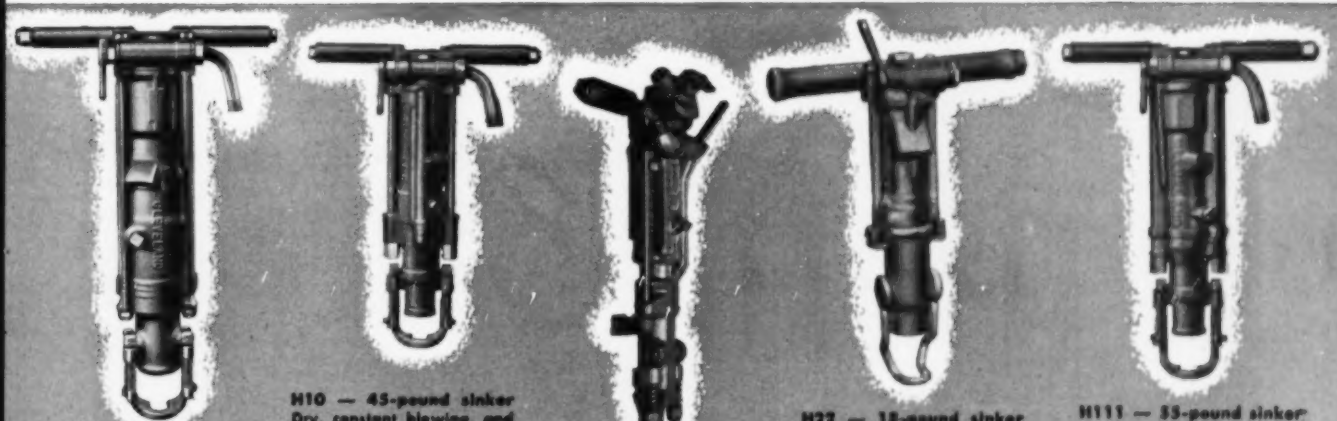

H23 — 83-pound sinker Dry and wet types. 1"x4⅛" hex or quarter-octagon. 1⅛" or 1⅜" lug shank. Designed for shaft sinking in hard rock or bad, faulting ground . . . general drilling with heavy steel in hard rock.

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RD-58

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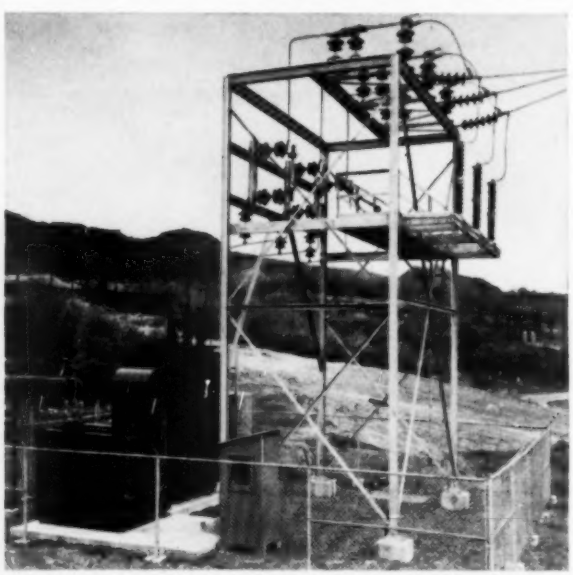
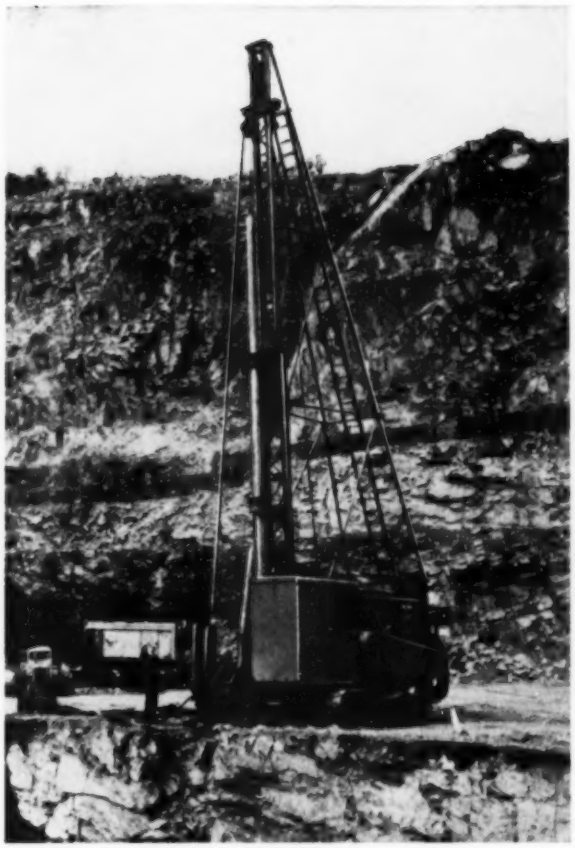
5 ways modern electrification can

4 MAKE POWER SYSTEM MORE FLEXIBLE. This standard G-E cable-skid switch house has polarized couplers to simplify and speed up cable interchanging. Skid house is easy to move.



5 IMPROVE POWER SYSTEM PROTECTION. Magne-blast breakers in G-E master unit substation protect feeders; lightning arresters help guard substation against outage.



2 **INCREASE DRILL FOOTAGE.** This self-contained churn drill, powered by G.E., delivers rapid rock penetration—promoting more efficient drilling and blasting practices.

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660-29

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GENERAL ELECTRIC

Meet The Authors

C. C. BAILEY

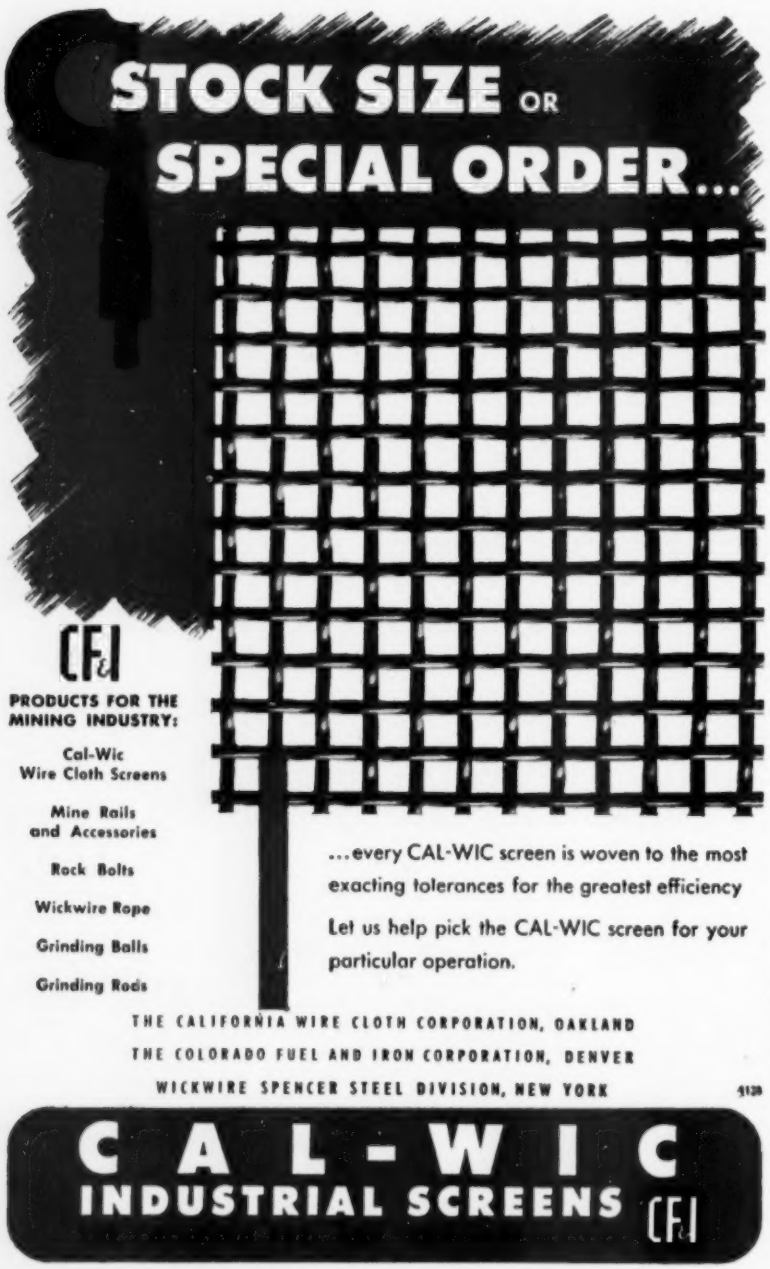
Carroll C. Bailey (P. 584) spent three and one half years in Hawaii doing engineering work before embarking on a 25 year career in the investment business. He has been with Paine, Webber, Jackson and Curtis for the last four and one half years as a specialist in mining and metal securities. Mr. Bailey was Phi Beta Kappa at Amherst College, and a member of the track and swimming teams. He also belonged to several music groups at school.

A. E. MOSS

A. E. Moss (P.593) spent the summers between 1932 and 1938 with private companies and the Geological Survey of Canada engaged in geological mapping and directing exploration work in various parts of Northern Canada. He worked in the underground operations of the Delnite Gold Mines, taking over as geologist during his last three months with the firm. Mr. Moss spent the last 11 years on the Labrador iron ore project of the Iron Ore Co. of Canada, directing drilling and orebody development. He is currently in charge of all Iron Ore Co. exploration. He is a graduate of the University of Saskatchewan and McGill University, earning a Ph.D. at the latter school. Wrestling and soccer furnished athletic outlets at school. While at McGill he held the Siscoe Scholarship for two years. Today, photography and curling are his hobbies.

J. K. GUSTAFSON

J. K. Gustafson (P. 593) of the M. A. Hanna Co. names golf, tennis, and photography as his spare time interests. He is a Harvard Ph. D., earning his Bachelor of Arts at Washington University. After a period of teaching at Harvard he went to work for the U. S. Geological Survey. Mr. Gustafson also worked for Homestake Mining Co., Hollinger Consolidated Gold Mines, Western Mining Corp., and many other firms. He was a member of the first Hollinger expedition to Labrador and Ungava. An AIME member as well as a Fellow of the Geological Society of America and Canadian Institute of Mining and Metallurgy, he has written many professional and technical papers.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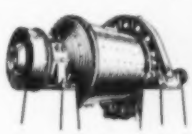
Allis-Chalmers know-how and equipment have been playing a leading role in the processing of taconite. A-C research laboratory tests, along with pilot plant operations and field work, have revealed valuable data on the processing of low grade iron ore. Crushers, vibrating screens and grinding mills furnished by Allis-Chalmers are already helping to solve the problem of taconite processing on the Mesabi range.

This *unsurpassed* background and experience on taconite, as well as A-C's many years of successful accomplishments on other ores, is available to you when you call an Allis-Chalmers representative. Phone the A-C man nearest you today, or write Allis-Chalmers, Milwaukee 1, Wisconsin.

A-3997

ALLIS-CHALMERS



Grinding Mills

Sales Offices in Principal Cities in the U. S. A. Distributors Throughout the World.

Vibrating Screens

Jaw Crushers

Gyratory Crushers

Hammermills

Kilns, Coolers, Dryers

Proof that mining men find it profitable to specify Allis-Chalmers grinding mills is seen in the fact that 7 *out of 10* A-C mills sold today are repeat orders!

When loading in a pitching vein the Eimco centers as it clears the muck pile — cleans up easily under the hanging wall.

CONSISTENT LOADING

"Our Eimco turns in a consistently good loading job," says one operator. "You can always depend on it although it requires only a minimum of attention and practically no maintenance."

Eimco's are heavy-duty machines with gear trains running in oil completely sealed in their heavy alloy-steel cases. Easy to operate, it has wide clean-up with automatic centering to load cars full all the way back.

For rock loading there is no equal to Eimco performance, dependability and economy.

Write for more information on the Eimco best suited to your job.

EIMCO 1448

You can't beat an Eimco

THE EIMCO CORPORATION

The World's Largest Manufacturers of Underground Rock Loading Machines

EXECUTIVE OFFICES AND FACTORIES — SALT LAKE CITY 10, UTAH, U. S. A.

BRANCH SALES AND SERVICE OFFICES:

NEW YORK 51 52 SOUTH STREET • CHICAGO 3319 SOUTH WALLACE STREET
BIRMINGHAM, ALA. 3140 FAYETTE AVE. • DULUTH, MINN. 216 E. SUPERIOR ST.
EL PASO, TEXAS, MILLS BUILDING • BERKELEY, CALIF. 637 CEDAR STREET
KELLOGG, IDAHO, 107 DIVISION ST. • LONDON W. 1, ENGLAND, 190 PICCADILLY

IN FRANCE: SOCIETE EIMCO, PARIS, FRANCE
IN ENGLAND: EIMCO (GREAT BRITAIN) LTD., LEEDS 12, ENGLAND
IN ITALY: EIMCO ITALIA, S.P.A., MILAN, ITALY

Eimcos moving earth for fill to build major link in Pan American highway in South America.

MOVING MATERIAL *Fast*

Building levees, highways, for bulldozing, clearing boulders from highways — any job that requires low cost earth or rock moving is best done with Eimcos.

These rugged, heavy-duty loading machines are finding their place in state highway departments, county and municipal road jobs, in sand and gravel pits, in steel mills and among contractors on heavy construction and airport jobs.

Investigate the cost of handling material the Eimco way before you buy.

Above: As a bulldozer. Below: Road building job in Austrian Alps. The shape of the Eimco bucket and the rocker-arm digging action make it possible to pick up and move pieces much larger than with other equipment.

EIMCO A449

THE EIMCO CORPORATION

The World's Largest Manufacturers of Underground Rock Loading Machines

EXECUTIVE OFFICES AND FACTORIES : SALT LAKE CITY 10, UTAH, U. S. A.

BRANCH SALES AND SERVICE OFFICES

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You can't beat an Eimco

Manufacturers News

New Products • FILL OUT THE POSTCARD FOR MORE INFORMATION • Equipment

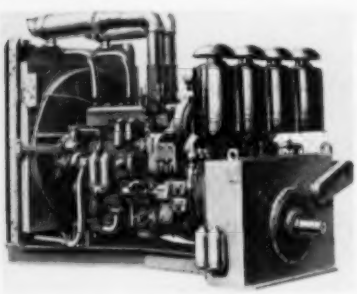
Side-Dump Truck

Easton Car and Construction Co. recently delivered to an overseas mining operation the largest of its type of lift door side dump truck body, mounted on Dart model 300

Diesel powered 6-wheel chassis. With a capacity of 30 tons of iron ore the floor plates are of 4x1-in. abrasive resistant steel. Dumping is by external overhead hoist. **Circle No. 1**

Twin Diesel

Detroit Diesel Engine Div. of *General Motors Corp.* recently showed a new Twin 6-110 Diesel producing 392 hp continuous rating at 1600 rpm. The unit has a maximum intermittent rating of 500 hp at 1800 rpm. Already proven in oil drilling the engines are provided with "dumping" type torque converters between



engine and compound permitting either engine to be disengaged from the load and eliminating need for clutches. A single fan cools both engines of the compact and portable unit. **Circle No. 2**

Plastic Core Wire Rope

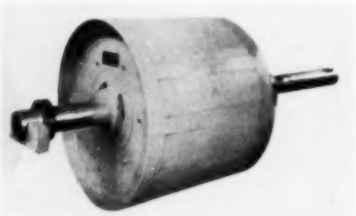
Production of a wire rope with a plastic core, said to be first product of its kind, has been announced by *Jones & Laughlin Steel Corp.* Developed for use in drilling the rope has a core of extruded polyvinyl. The plastic is stated to be unaffected by acids, caustics and other sub-surface substances which can destroy fiber cores. **Circle No. 3**

Steel Hardening Compound

Hard-N-Tuff is trade name of powdered steel hardening compound marketed by *Doughty Laboratories Inc.* for which spectacular improvements in wear resistance are claimed. Product is said to require only minutes for application and 300 pct increase in resistance to abrasion is claimed. **Circle No. 4**

Magnet Pulley

A large magnetic pulley has been built by *Stearns Magnetic, Inc.* for treating run-of mine coal up to 10-in. lump size at belt speeds of 300 fpm



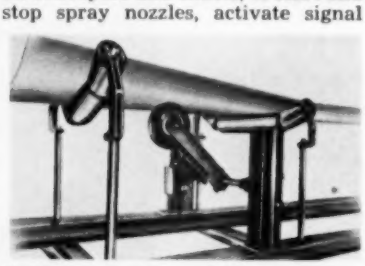
with capacity of 300 tph. Alnico V alloy provides the power for what is said to be largest permanent magnet pulley ever built. **Circle No. 5**

Loading Platform

A completely automatic loading platform developed by *Field Engineering Co.*, is started from the loading dock by the front wheels of the materials-handling truck, and a leveling ramp automatically stops the Load-O-Matic on the same level as truck floor. **Circle No. 6**

Conveyor Controls

Two devices are now available from *Johnson-March Corp.* for use on conveyors and chutes, to start and stop spray nozzles, activate signal



lights, or control auxiliary conveyors or equipment. The model UB control for under-the-belt use is sensitive to deflections of 1/16 in. or more, and the model 4A control is a paddle control. **Circle No. 7**

New Shop for Yuba

Yuba Mfg. Co. announced completion at Benecia, Calif., of a new structural shop with 40,000 sq ft of space for building of placer dredges and other equipment. **Circle No. 8**

Bin-Dicator

Lower prices on certain models of their bin level indicators have been announced by the *Bin-Dicator Co.* In addition to price reduction on models A and C, improvements have been made in access, and installation. **Circle No. 9**

Labels

Pre-cut, self-sticking Write-On labels made by *W. H. Brady Co.* combine printed form and write-on space in labels detached from cards. **Circle No. 10**

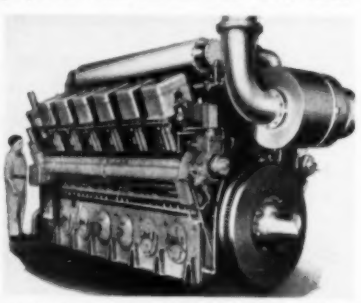
Turbomill

The Turbo-Mill, developed and perfected in Germany where it is claimed to be in use by over 500 manufacturers and processors, is now distributed by *A. E. Poulsen & Co.* in the U. S. The mill is claimed to dis-

integrate and shred a wide variety of materials at extremely high speed, utilizing what are stated to be all four principles of grinding and pulverizing; compression, attrition, cutting, and shredding. **Circle No. 11**

Heavy Duty Diesel Engine

Designed to meet increasing demand for heavy duty prime movers of moderate weight and compact physical dimensions the new four-



cycle Supairthermal V-type engines introduced by *Nordberg Mfg. Co.* for stationary or marine service come in 12 or 16 cylinder models to provide 2400 to 4260 hp at 450 to 600 rpm. Engines are built in Diesel, Duafuel, or Spark-fired types. **Circle No. 12**

Free Literature

(21) PLANT DESIGN: A bulletin from *The Dorr Co.* outlines the advantages of engaging a "specialist" engineering firm for design of phosphoric acid, triple superphosphate, ammonium phosphate and complete fertilizer plants. Included are descriptions of systems and typical flowsheets developed by Dorr for recent projects.

(22) SAFETY SERVICE GUIDE: *The National Safety Council's* new "Occupational Safety Guide" provides safety directors with a complete catalog of the many varied accident prevention aids available from the Council. The 52-page book offers periodicals, newsletters, and a complete library covering all aspects of occupational accident prevention, as well as posters, films, and other on-the-job materials.

(23) DIESEL POWERED TRUCKS: An 18-page illustrated booklet from *Euclid Road Machinery Co.* describes the wide range of *General Motors* powered Euclid equipment for use in stripping, open-pit, and construction projects.

(24) MINERAL JIGS: *The Denver Equipment Co.'s* selective mineral jig is fully described in a recent bulletin. Flowsheets, diagrams, photographs, and cutaway views are supplemented by text showing where the Denver Jig fits into the flowsheet.

(25) PORTABLE CORE DRILL: The Teredo core drill built by the *Acker Drill Co.* was designed to fill need for a portable medium duty unit capable of depths to 600 ft. Their bulletin illustrates major features, gives specifications, and provides a picture story of the drill in action.

(26) DOUBLE ROLL CRUSHERS: A new catalog on Telsmith double roll crushers has been published by *Smith Engineering Works.* Available in 24x16, 30x18, and 40x22-in. sizes, these crushers are suitable for reducing large capacities of fine aggregate at low reduction ratios.

(27) HIGH CAPACITY V-BELTS: High capacity Texrope belts for tough jobs are described in a new bulletin released by *Allis-Chalmers Mfg. Co.* Carrying 40 pct greater horsepower rating, the belts are oil resistant and static conducting, and recommended for tight spots, for compactness, and for changed peak loads.

(28) FLOTATION INFORMATION: Considerable information on the use of Rosin Amine D acetate as a silica collector, and tabulated shipping information are included in the revised, 1953 edition of "Flotation," technical booklet from *Hercules Powder Co.*

(29) VARIABLE SPEED DRIVE: *Reeves Pulley Co.* has issued a bulletin on their Flexi-Speed drive, newest addition to Reeves line of variable speed drives and controls.

(30) LUBRICANT PUMP: A new, small automatic pumping unit designed to provide dependable lubrication for single machines is described in *Farval Corp.* bulletin. The DC-20 unit delivers 1.5 fluid ounces per min of either grease or oil.

(31) CONE DRIVE GEARS: A new 4-page brochure entitled "Cone-Drive Gears at Work in Mining" now available from Cone Drive Gears Div. of *Michigan Tool Co.* shows use of their equipment in continuous coal mining machines, conveyors, work platforms, and car spotters.

(32) CONTINUOUS WEIGHING: Transportometer Div. of *Sintering Machinery Corp.* offers a bulletin covering a complete line of continuous, automatic weighing scales. Transportometer is an installation for belt conveyors, Transportoweigher is a complete weighing and conveying unit, and Transportofeeder is a complete feed regulating, weighing and conveying unit.

(33) WIRE ROPE DATA: Latest information on the "one best wire rope" to use on each type of mining equipment has been incorporated in a booklet offered by the American Cable Div. of *American Chain & Cable Co.*

(34) DIRECT READING Btu METER: An information sheet from *Minneapolis-Honeywell Regulator Co.* describes application and operation of the Brown Instruments Div. Btu meter that records differential temperature and liquid flow. Direct readings in Btu are provided for applications in heat transfer study and recording of thermal data in pilot plants.

(35) INDUSTRIAL BELTS: A catalog available from *Thermoid Co.* on industrial V-belts features simplified conversion tables for determining correct belt selection. Prices, weights, and construction details are presented.

(36) CONVEYOR BELT DATA: B. *F. Goodrich Co.* has published a 32-page manual on installation and maintenance of conveyor and elevator belting. Over 60 photographs and drawings illustrate ways to improve belt service and lengthen belt life. Belt repair, splicing, fastening, and review of engineering data required for specification of conveyors are other topics.

(37) POWER DISTRIBUTION: A new bulletin announced by *General Electric Co.* serves as a guide for

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after September 15, 1953 — if mailed in U. S. or Canada

Please send me { More Information ☐ / Free Literature ☐ / Price Data ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
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Students are requested to write direct to the manufacturer.

Name..... Title.....

Company.....

Street.....

City and Zone..... State.....

plant engineers on electric power distribution practices in large and small plants. Entitled "Industrial Power Distribution Idea Book," the publication covers power distribution and purchase, choice of voltage, and selection of primary switches and circuit breakers.

(38) COAL HANDLING: *Goodman Mfg. Co.* recently issued two new catalogs, one covering cable reel shuttle cars, and the other on the type L-14 shaker conveyor drive for low coal. Dimensions, specifications, and illustrations are provided.

(39) MATERIALS HANDLING: Loading and unloading equipment for cars and ships is the topic of the latest *Stephens-Adamson Mfg. Co.* bulletin. Photographs and diagrams tell the story of equipment designed to put materials in hard-to-reach spots at minimum cost and maximum speed.

(40) SCIENTIFIC APPARATUS & CHEMICALS: Most frequently ordered items in the *Burrell Corp.* line of scientific apparatus and laboratory chemicals are described in price list now available.

(41) TRACK MATERIALS & SUPPLIES: Savings in time and money through single source buying of track materials and supplies are pointed up in a new catalog issued by *L. B. Foster Co.*

(42) SUPERCHARGED COMPRESSOR: Stated to be the first turbocharged, 2-cycle, gas-engine-driven compressor, the *Clark Bros. Co.* Turbocharged Right Angle model TRA compressor is claimed to offer high thermal efficiency with resulting lowered fuel consumption and cooling water requirements. A new catalog provides full details of this new development in compressors.

(43) METALLURGICAL MICROSCOPES: A brochure issued by *R. Y. Ferner Co.* describes the complete line of Cooke metallurgical microscopes. Of special interest are the Incident Light Phase Contrast device and the Universal illuminator, exclusive Cooke items.

(44) DIESEL-ELECTRIC POWER: "Power" is title of booklet issued by *Caterpillar Tractor Co.* devoted to explaining efficient and economical use of Diesel-electric sets in industry. Basic sizes of Caterpillar electric sets and photographs of applications are features.

(45) ELECTRIC RELAYS: A complete line of general purpose relays featuring longer life and greater flexibility of application is described in a *General Electric Co.* bulletin.

(46) CONVEYOR BELT REPAIR: Information on use of Magic-Vulc plastic rubber for conveyor belt repair is contained in folder from *Magic Chemical Co.* Applicable to worn spots without removing belt from pulley, the compound is stated to greatly increase possible belt life.

(47) SAFETY TROLLEY SYSTEM: *Universal-Standard Inc.* has issued an illustrated leaflet on their new U-S Safety Trolley system for application to ore bridges and mine electrification. A conductor surrounded by an insulating sleeve carries loads from 50 to 2000 amp, while providing maximum safety.

(48) MINE PHONES: Use of the *Mine Safety Appliances Co.'s* Mine-Phone for clear, two-way voice communication throughout mining operations is pictured and described in a new bulletin.

(49) STATIONARY DIESEL ENGINES: Lister 4-cycle stationary Diesel engines of 8 to 27 hp are distributed by the *National Supply Co.* A folder giving engine weights, dimensions, and technical data on the one to three cylinder units is now available.

(50) EARTH MOVING: All types of earthmoving equipment manufactured by *Euclid Road Machinery Co.* are covered in a 48-page book recently issued. Rear-dumps, bottom-dumps, scrapers, and loaders are illustrated along with job views of them at work.

(51) RUBBER LINED PUMPS: Reasons why pressure molded rubber parts in *Denver Equipment Co.'s* SRL pumps maintain high efficiency for prolonged periods are illustrated in a recently published bulletin giving case histories, design, and specifications.

(52) PNEUMATIC CONTROLLERS: *Fischer & Porter Co.* are distributing a catalog on the completely new P-4 Pneumatrol pneumatic controller for rate of low, differential pressure, liquid level, viscosity, pressure, and temperature applications.

(53) SELF-CLEANING STRAINER: *S. P. Kinney Engineers Inc.* has available a new booklet containing complete descriptions of the Brassert and Kinney automatic self-cleaning strainers, and the Kinney manual model.

(54) SCREW CONVEYOR BOOK: Comprehensive information on screw conveyors and screw feeders is provided in a 92-page book released by *Link-Belt Co.*

(55) WIRE AND CABLE DATA: *U. S. Rubber Co.* has published a 76-page booklet on electrical wire and cable for chemical and petroleum industry application that provides data on butyl insulation, heat and moisture resistant insulation, and other special-purpose wiring material.

(56) BAG HANDLING: "The Logistics of Bags" is title of colorful booklet offered by *Elwell-Parker Electric Co.* The literature is designed to help effect economies in handling loads in plants and warehouses, and describes the handling cycle from receiving through shipping.

(57) COAL WASHING TABLE: Information on the new model LTH coal washing table has been released in a bulletin from the *Deister Machine Co.* Several new features combined in the model LTH include the Lifetime Anti-Friction Headmotion, and an improved deck contour, together with a new riffling system for automatic control of coal-refuse separation. Foundation and installation data are given in the booklet.

(58) HIGH HEAD PUMPS: Type TU pumps for circulating, supplying and boosting water and clear liquids at medium and high heads were designed with special emphasis on long pump life. The pumps are illustrated in a catalog from the Peerless Pump Div. of *Food Machinery and Chemical Corp.*

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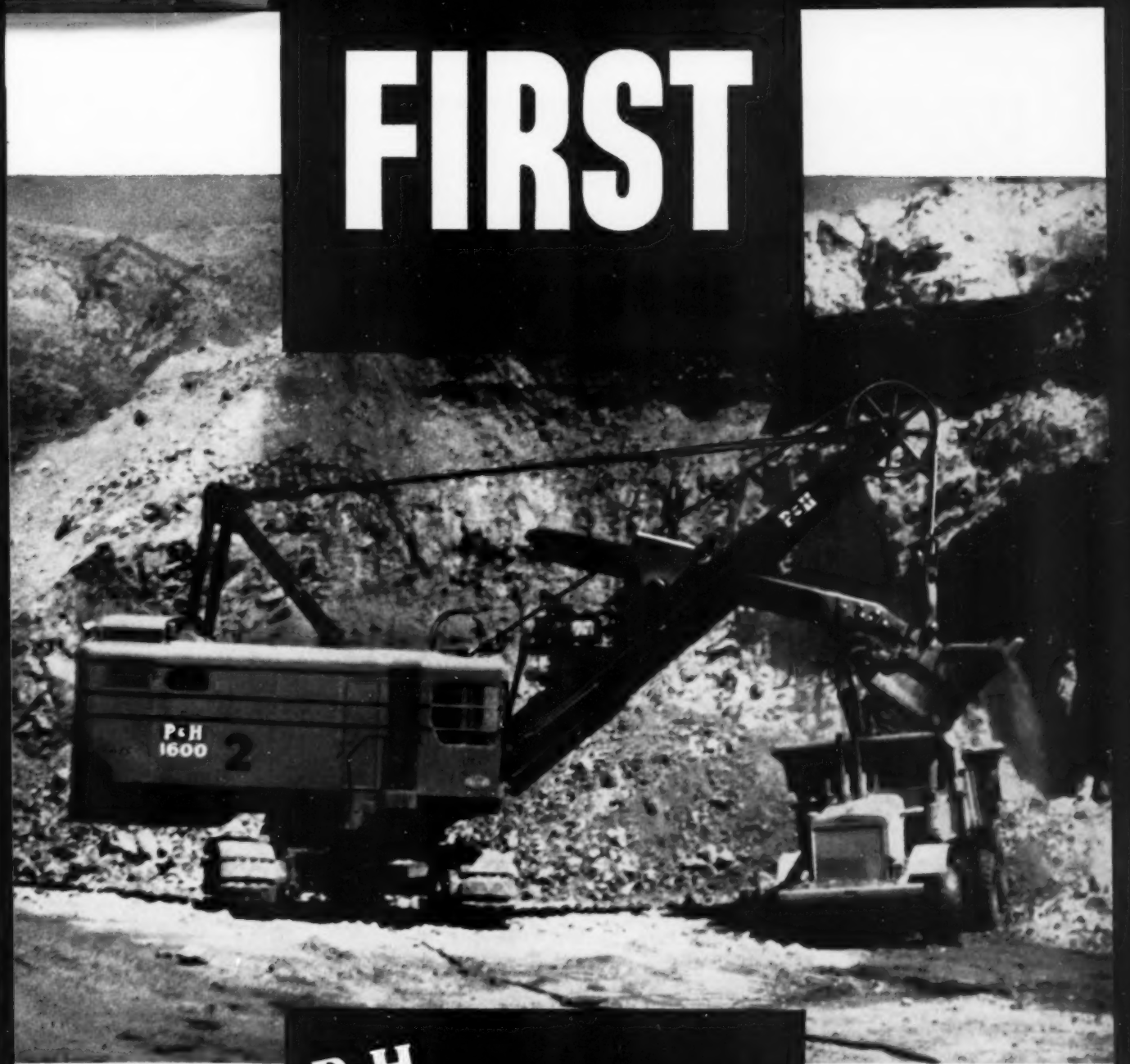

P&H

The first thing you see when you look into P&H Electric Shovels is new ideas—ways of doing things differently. *Differently and better!* For P&H engineering concentrates on one thing . . . cutting *your* production costs!

The result is evident in electrical equipment designed and built by P&H—especially for the purpose—not adapted for it. Stepless power regulation gives you the smoother flow of power without multiple contactors to cause trouble and replacements. There's Magnetorque* Hoist Drive, vertical swing motors, independent propel, powerful worm crowding mechanism with separate crowd motor, air-filtered cab. And there's the all-welded strength of rolled alloy steels to take year-in, year-out punishment.

P&H leadership in electric shovel development gives you leadership in all kinds of open pit work . . . lower tonnage costs! That explains why every third P&H Electric Shovel sold is a repeat order. Get the facts.

*T. M. of Harnischfeger Corporation for electro-magnetic type coupling.

P&H LARGE EXCAVATOR DIVISION

HARNISCHFEGER CORPORATION

MILWAUKEE 46, WISCONSIN

the P&H *Line*

This 11½ x 12 ft. Ni-Hard Lined Rod Mill replaced 2 sets of 74" x 20" rolls with accompanying screens and conveyors for handling lead and zinc sulphide ore at the Sullivan concentrator of THE CONSOLIDATED MINING & SMELTING COMPANY OF CANADA LIMITED. (Balls placed to show size and spacing of liners are 3" in diameter.) This mill, which operates with a 76-ton charge of 3½" rods and is designed to handle 400 tons of ore per hour, is a product of the HARDINGE COMPANY, INC., York, Pa.

Four-years' service indicates 6,750,000-ton life for Ni-Hard liners in world's largest rod mill

Performance Records Prove It: NI-HARD® *provides abrasion-resistance at lowest ultimate cost...*

And the reason? With a matrix resembling that of fully hardened steel, this moderately priced nickel-chromium white cast iron is the most abrasion-resistant product of the foundry industry.

Shown in the Hardinge Rod Mill, above, are the original Ni-Hard shell and discharge end liners. The end liners are still in use and after four years of milling approximately 8,000 tons of ore per operating day, it is conservatively estimated that their total life will approximate 6,750,000 tons. The shell liners were replaced after a life of 5,700,000 tons. The probable total consumption for both shell and end liners will reach the extremely low figure of 0.010 pounds per ton.

Take steps, now, to save labor and cut maintenance as well as operating costs by using Ni-Hard for your equipment parts subject to wear and abrasion. Our wide practical experience, gained over the past 20 years in the Ni-Hard field, is available to help you determine *whether or not* Ni-Hard is the best answer to your particular needs. Send us details of your problems for our suggestions. Write us now.

At the present time, nickel is available for the production of Ni-Hard and other alloys containing nickel, for end uses in defense and defense-supporting industries. The remainder of the supply is available for some civilian applications and governmental stockpiling.

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THE INTERNATIONAL NICKEL COMPANY, INC.
Dept. 20, 67 Wall Street, New York 5, N. Y.

Please send me free booklets entitled: "Engineering Properties and Applications of Ni-Hard" and "Buyers' Guide for Ni-Hard Castings."

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

University of Nevada's recent Bonanza Days celebration turned out to be the real thing when Kennecott Copper Co. presented the school with $30,000 for new laboratory equipment for the MacKay School of Mines. J. C. Kinnear, Jr., general manager of Kennecott's Nevada Div., handed the check to Minard Stout, university president.

Chemical Construction Inter-American Ltd., signed a contract with Noranda Mines, Ltd. for construction of a sulphur-iron plant in the Niagara Peninsula. Work has been started and it is expected that the plant will be finished by summer 1954.

Milling capacity of Vanadium Corp. of America vanadium-uranium properties in the Colorado Plateau was increased through addition of a roaster at the Durango, Colo., plant. Vanadium Corp. also started construction of chromium ore concentrator at its Southern Rhodesia properties.

Improved blasting techniques and reduced breaking costs resulted from use of millisecond-delay detonators at the Bureau of Mines experimental oil shale mine at Rifle, Colo. When used correctly the detonators resulted in better fragmentation, economical explosives use, and compact, easily loaded muck piles. Blasts were recorded by a high speed motion picture camera, employed for the first time underground.

Atomic Energy Commission approved addition of 12 companies as associates with Dow Chemical Co., and Detroit Edison Co., in a joint study with the AEC of the possibility of a nuclear reactor producing power. Total number of companies now associated with the Dow-Detroit project is 25.

Regulations under which the Government, through DMPA, helps finance exploration for new deposits of strategic minerals have been amended. Program is now restricted to those minerals still in critical short supply. Nineteen separate minerals or metals have been eliminated from list of 37 previously eligible for assistance. Amendment 2 to DMEA Order-1 covers the change.

United States Smelting, Refining, & Mining Co. will again offer three four-year scholarships to the University of Utah College of Mines and Mineral Industries, beginning with the 1953 fall quarter. Each scholarship is worth $500 annually. Holders are given an opportunity to work in a company plant during summer vacations.

Sen. Guy Cordon (R-Ore.) is reportedly backing a bill giving the states deeded off-shore oil rights, only oil and natural gas deposits, reserving all other minerals on the Continental Shelf to the Federal Government.

Defense Minerals Procurement Agency virtually suspended all allocation controls on manganese ore. After June 1, the only provision left in effect authorizes DMPA to issue special directives covering manganese ore deliveries.

The titanium supply situation is reportedly so tight that DMPA has made a short term contract with the Bureau of Mines for delivery of 500,000 lb of the metal during the next 18 months. Delivery will be made from the Bureau's experimental station at Boulder City, Nev.

Wherever ores are processed . .

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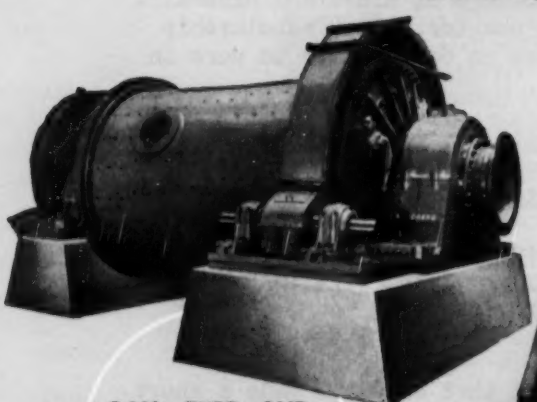
GYRATORY AND CONE CRUSHERS FOR PRIMARY, SECONDARY AND FINE REDUCTION CRUSHING



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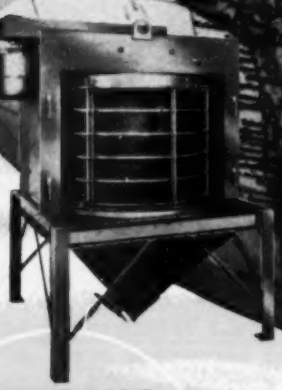

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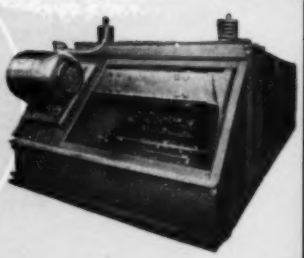

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THE RARER ELEMENTS . . . NON-METALLICS AND MINERALS . . .

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MINING MACHINERY

is the *outstanding* choice of producers THE WORLD OVER!

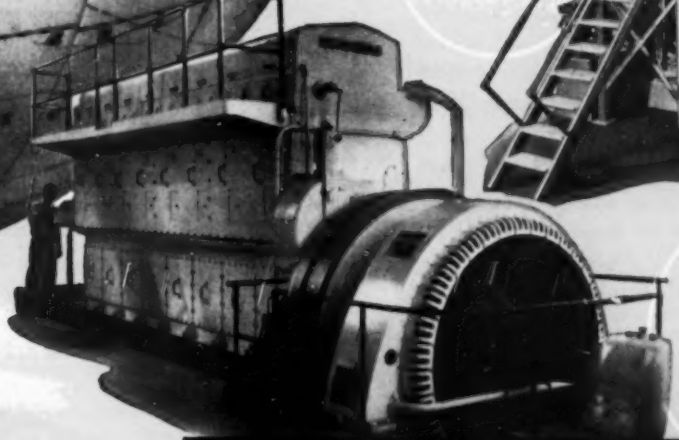
● Without the vast ore processing operations in all parts of the globe, all industrial capacity would be seriously hampered. And without efficient, large-capacity mining machinery, these ore and mineral processing operations would fall far short of their required output.

It is highly significant that *wherever* mineral resources are found in quantity — efficiency minded producers are now using, or are in the process of installing, Nordberg Mining Machinery.

This dependable Nordberg Machinery is designed and built especially for the Mining Industry . . . and includes Mine Hoists; *SYMONS* Gyratory Crushers for primary breaking; *SYMONS* Standard and Short Head Crushers for fine reduction crushing; *SYMONS* Vibrating Grizzlies and Screens for scalping and sizing; Grinding Mills for wet or dry grinding; and a complete line of heavy duty Nordberg Diesel Engines in sizes from 10 to 10,000 H.P.

Write for literature on the machinery you need.

MINE HOISTS



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2 and 4-cycle—
10 to 10,000 H.P.
Burn Gas, Oil or any combination of both

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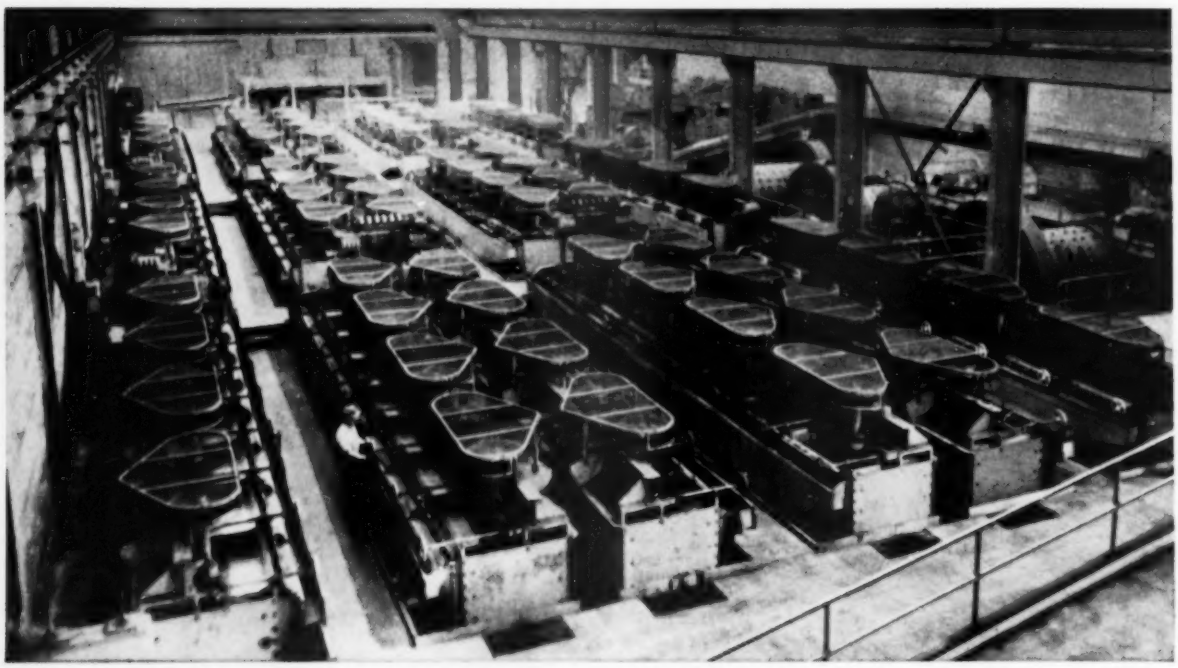
CUT FLOTATION COSTS WITH DOW XANTHATES

Superior collectors increase profits by providing greater recovery, higher concentrate grade of sulfides



With Xanthates on the job every bubble is loaded to capacity, increasing your recovery and raising your concentrate grade. Because of their greater efficiency in fast, complete separation of the sulfide minerals, Dow Xanthates save you money.

For more efficient differential flotation, Dow offers a wide range of Xanthates of extremely selective collector power. Since all of these collectors are essentially nonfrothing, the operator enjoys complete freedom to regulate the frother and the collector independently.

For further information and test samples of Dow Xanthates, write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. OC 3-47.

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DOW

Bauxite forms a miniature mountain at Kaiser Aluminum Co.'s Baton Rouge plant. The ore comes from Kaiser properties in Jamaica. The company expects to mine bauxite on the Island for the next 50 years at least.

Kaiser Sees Bright Future for Jamaica

Kaiser Aluminum Co. has a big stake in the British West Indies, the Island of Jamaica in particular. There, Kaiser is busy developing one of the most promising bauxite finds in recent years. The $12 million operation was officially opened in February.

Facilities have a rating of an annual capacity of 2 million tons and will supply Kaiser plants with ore for years. The ore comes across the Gulf of Mexico, up the Mississippi to stockpiles at Baton Rouge. The stockpile at Baton Rouge would throw many an old river boat skipper for a loss. Where no mountain once existed now stands a man-made bluff of bauxite, known as Bauxite Peak.

At Jamaica, Kaiser owns or has under option sufficient reserves to supply its operations for the next 50 years, according to company officials. The S.S. Evanthia, plying between Port Kaiser, Jamaica, and Baton Rouge, takes on a 10,000-ton load for each trip to the states.

Docking facilities at Port Kaiser were built by the company. Kaiser is changing the landscape of Baton Rouge as well as Jamaica. It's a long way from the blue waters surrounding the Island to the muddy Mississippi, but the tie grows stronger with each shipload of bauxite. Kaiser is expanding its alumina production, in line with the U. S. defense objective, and the Jamaica development is another step forward in its overall plan to help meet the needs of the country.

SS Evanthia takes on a 10,000-ton bauxite load at Port Kaiser, Jamaica. Kaiser facilities on the island will have an annual capacity of about 2 million tons.

U. S. Steel Plans New Limestone Quarry

Construction work for a new limestone quarrying and processing plant at Cedarville in Michigan's Upper Peninsula was scheduled to start in April, according to Hugh S. Lewis, president of U. S. Steel Corp.'s Michigan Limestone Div.

The project is expected to produce 3 million tons per year of metallurgical quality limestone. Actual quarrying will take place on a 10,000 acre site five miles northeast of Cedarville. It is expected the plant will be in operation by late 1954.

Stone will be crushed at the quarry and transported by rail to screening plant and dock facilities located at a point between McKay and Bush Bay.

Sen. Dworshak Aims At Mine Law Change

A bill designed to prevent, prior to patenting, the use of mining claims for any purpose other than prospecting, mining, or processing operations and uses reasonably incident to such work was introduced by Sen. Henry Dworshak (R-Idaho).

The bill would permit the Government use of the surface of the claims for grazing, reforestation, fire prevention, and like matters. It would give the miner the right to cut timber needed for his operation but no more.

Senator Dworshak pointed out that mining laws were never intended to supply lands "for the purpose of obtaining valuable timber rights, cabin sites, filling station locations, recreational areas, etc."

The laws were created to encourage "exploration, development, and mining of the minerals and metals lying hidden in the earth and to make them available to our economy and the benefit of our nation," the Republican senator added.

Sen. Dworshak said his bill would accomplish this and still not interfere with mineral resources development. The same measure is being introduced into the House by Rep. Wesley D'Ewart (R-Mont.).

Reach Three-Way Pact For Bolivian Tungsten

A three-way agreement for the purchase of tungsten ore between U. S. representatives, the Bolivian Government, and former owners of the nationalized Patino mines was reached by the General Services Admininstration.

President Victor Paz Estenssoro said similar agreements are being negotiated with the former owners of the Hochschild and Aramayo mines. The Bolivian president said the U. S. demanded that an agreement on compensation with owners of nationalized mines be reached before resuming negotiations for the purchase of tin.

With the agreement negotiated, Mr. Paz Estenssoro is said to have commented, "We will put the sincerity of the U. S. to the test."

The Bolivian head man said the new contract with GSA calls for a price of $63 per short unit of 20 lb of ore compared with the current price of $40 per short unit. Patino will receive $10 of the amount against future indemnization by the Government for nationalization. An additional $10 will be set aside to repay an Import Export Bank loan for development of Bolivian tungsten.

Deadweight Down Payloads Up with

LAKE SHORE MINING EQUIPMENT

Skips and Cages—all types.

Sheaves—Roller Bearing, Rotating Shaft and Split Type Bicycle Sheaves . . . Cast Iron, Steel and Aluminum Idler Sheaves.

PRODUCTION INCREASES OF 8% and more have been recorded with the installation of Lake Shore engineered mining machinery, like the aluminum and steel Jeto Bottom Dump Skip (above). Lake Shore mining equipment is designed and built by men who know the field, men who know where and how to use weight-cutting aluminum, how to round the corners of tram car for greater rigidity and cleaner dumps . . . men who originated the roller bearing bicycle type head sheave and bell mouth idler sheave.

Lake Shore's experienced engineering is at your disposal either in existing models, or for the design of special machinery your operation may require.

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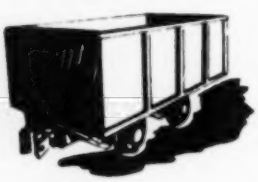

Mine Cars—Lohed Tram Cars, Granby Type, Self-propelled Trestle Cars, Man Haul Cars.

LAKE SHORE Engineering Company

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Look to Lake Shore for Leadership

Hudson Bay Mining Reports on Claims

Hudson Bay Mining & Smelting Co. reports that its Tom Claims stake in the Yukon territory has revealed 9 million tons of low-grade lead-zinc-silver ore. Another property, a nickel-copper orebody, has showings of gold-platinum-palladium, as well as some cobalt. The property is in the Klaune Lake district and is located close to good highways leading to tidewater. It covers an area about 12 miles long and three miles wide comprising 538 claims, reported generally well mineralized.

Announce New Find Of Labrador Iron Ore

Premier Joseph Smallwood announced a find of high grade iron ore in Labrador. Fifty claims have already been staked. Mr. Smallwood said the find is in a section where the newly formed British-Newfoundland Corp. holds mining concessions.

Extensive drilling is planned during the summer to determine the amount of the ore. According to Mr. Smallwood, actual mining may begin within two years.

Drilling Contracts To Sprague & Henwood

Several contracts for diamond drilling in the Colorado Plateau area have been awarded to Sprague & Henwood, Inc. Contracts total about 270,000 ft.

The firm plans to open a new office at Grand Junction, Colo., to be known as the Western Branch. Sprague & Henwood has drilled hundreds of thousands of feet in the Plateau area.

Felix Wormser, left, chats with President Eisenhower a few minutes after receiving oath of office as Assistant Secretary of the Interior in charge of Mineral Resources. Mrs. Wormser looks on. Mr. Wormser is a former executive of St. Joseph Lead Co.

Eisenhower Sees Mining Vital to U. S. Security

The U. S. must find a mining policy "equitable to all concerned," President Eisenhower said in a recent letter addressed to Rep. Ed Edmonson (D-Okla.).

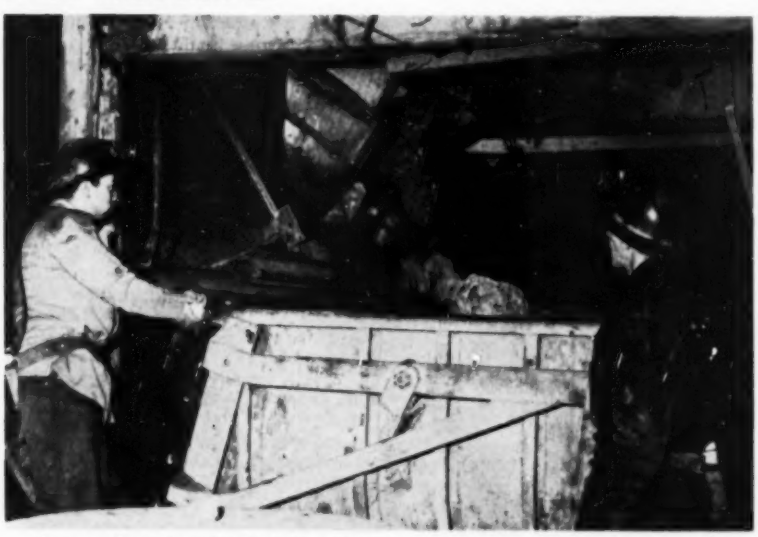
"A strong domestic mining industry is vital to national security and to the continued prosperity of our country," the President said. The letter resulted from material presented to Mr. Eisenhower by Rep. Edmunson to show the adverse effect of imports of zinc on zinc mining operations in the tri-state area of Oklahoma, Missouri and Kansas.

The letter was read to the House Ways and Means Committee considering proposals to extend the reciprocal trade agreements law for another year. The law expires June 12. A sliding scale import tax on lead and zinc was proposed by Rep. Richard M. Simpson (R-Pa.).

President Eisenhower said he was impressed with the seriousness of the situation. "I hope the administration may find a way of relieving the depressed conditions that prevail within many mining districts.

"The problem, of course, is one of determining what course of action may accomplish the purpose without endangering other policies essential to the security and economic welfare of this nation and other free world countries. We must find a solution that is equitable to all concerned, and I am encouraging the Congress and agencies within the executive branch to work toward that end."

STILL PRODUCING!

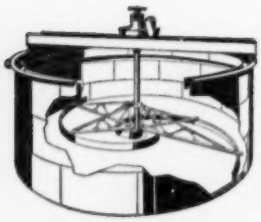


Iron ore drops through a boxhole at Ringwood mine, Ringwood, N. J., into a waiting car. Recently put back into operation, the mine is 213 years old. Ore from the mine went into guns for Washington and Grant. Reprinted from Esso Oilways

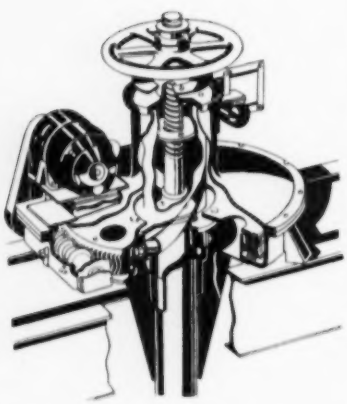
American Zinc, Lead Shuts Tennessee Mine

American Zinc, Lead & Smelting Co. closed one of its mines in Tennessee, according to Howard I. Young, president. No more closings are contemplated now.

Mr. Young added, however, that if lead and zinc prices continue to decline, the firm will reconsider operations of other properties. The Tennessee mine produced between 6000 and 8000 tons of zinc per year.



"AUTO-RAISE"
THICKENERS



One of the distinctive features of Hardinge Thickeners is the "Auto-Raise" driving mechanism, which automatically lifts the scraper away from an overload or obstruction in the tank bottom—eliminating costly breakdowns and delays. Bulletin 31-D-2.

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Steep Rock Iron Mines, Ltd. has been one of the leaders in Canadian mine development. Here, one of the open pit operations of the firm can be seen. Recently, Steep Rock leased rights to Inland Steel Co., long interested in Canadian iron ore development.

Lehigh Engineer Urges Intensive Coal Research

David J. Crawford, Lehigh Navigation Coal Co. mining research engineer, reporting on a mining research program for the anthracite industry said, "costs for labor and material have been increasing, whereas productivity per employee has been relatively constant."

He warned those attending the 11th Annual Anthracite Conference at Lehigh University, that as a result of this situation the price of a ton of anthracite has been progressively increasing. "Unless this trend is arrested, there is danger that the costs will reach a point where anthracite will not be on a competitive basis with other fuels."

He added, "Through mechanization, improvements can be made in current mining practices to increase safety, reduce the losses of minerals incident to mining, and lower mining costs."

Kennecott Gold Mine Near Production Stage

Progress in Kennecott Copper Corp. gold mining interests in the Orange Free State, South Africa was reported by Charles R. Cox, Kennecott president. A mill is under construction at the Virginia mine and production is expected to begin within a year.

Samples of ore from a new bore hole at the Merries Pruit mine show gold values somewhat higher than those of the original drilling. Interest in the Orange Free State development has increased with the discovery of small amounts of uranium in the gold ore, which can be recovered profitably as a byproduct.

Kennecott is also reported laying plans for development and exploration of bauxite deposits in British and Dutch Guiana. The plans are part of Kennecott's overall exploration program.

White Pine Copper Mine Development Progresses

Mine tunnel and portal are completed and underground work on the main service drift is underway at the White Pine copper development of Copper Range Co., in the Upper Michigan Peninsula.

Mill and smelter are not expected to be ready for about two years, and ore will be stockpiled as underground development progresses. Development is financed by an RFC loan of $57,185,000. Work done thus far, according to Morris F. La Croix, president, confirmed earlier estimates of copper content of the ore.

UMW Merge Districts As Membership Drops

United Mine Workers decided to consolidate four sub-districts of the Pittsburgh district in an economy move. Seven sub-districts were reduced to five by a special District 5 convention.

Membership rolls are reportedly down from 30,000 in 1951 to 19,000 now. John P. Busarello, district president, said reorganization is necessary because membership decline placed the district in a position where "it is extremely difficult to fulfill financial obligations." Sub-districts 1 and 2 were consolidated into one sub-district and sub-districts 4 and 5 into another.

To Build Huge Ore Carriers in Japan

London shipping trade representatives report that National Bulk Carriers, Inc. American ship designers and builders contracted with the Japanese Government for construction of three 60,000-ton ore carriers.

Keel for the first ship will be laid down at the former Kure Naval shipyard, operated by the American firm under an arrangement with the Japanese Government. The ships are reportedly to be the largest freight vessels in the world. They will have an overall length of 756 ft. National Bulk Carriers is building three 38,000 dead weight ton oil tankers of 645 ft in the Kure yard.

All machinery and equipment for the vessels will be of U. S. design and construction. Power will be supplied by steam turbines generating 13,000 hp and capable of 14 knots.

Austrian Bauxite Output Doubles 1951 Figures

Austria produced more than 15,000 metric tons of bauxite in 1952 compared with 8,000 tons in 1951, with a further increase expected for this year.

Sole Austrian bauxite deposits are in Unterlausse with about half the ore produced containing a high proportion of silicic acid, making it unsuitable for the manufacture of alumina. Alumina is processed from Austrian bauxite at Schwandorf, Bavaria.

French Approve African Manganese Venture

French mining companies and U. S. Steel Co. have approval of the Minister of French Overseas Territories to develop the manganese deposit in Gabon, North Africa, according to an official announcement.

The North African deposit is said to contain between 40 and 50 pct manganese with reserves estimated at 50 million tons. Mining will be by open pit.

Louisville & Nashville Purchases Rolling Stock

Anticipating a heavy movement of Venezuelan iron ore through the Mobile, Ala., port, the Louisville & Nashville Railroad plans to purchase 250 specially designed 95-ton ore cars at a cost of $2.5 million.

The Bessemer, Ala., plant of Pullman Standard Car Manufacturing Co., will build the rolling stock for delivery early in 1954.

The objective for this new potash plant was AS NEARLY AUTOMATIC OPERATION AS POSSIBLE, throughout every phase until the quality-controlled finished product is shipped.

3,000 tons of feed per 24 hours was the capacity sought, and every aspect of production and treatment was scaled to that figure.

Stearns-Roger engineered, designed, and constructed the plant—manufacturing special equipment in its Denver shops.

Early months of operation prove that owner and engineering contractor alike may stamp the project 'Mission Accomplished'

Another typical example of *complete* Stearns-Roger service to industry, with everything under one contract and responsibility undivided!

Stearns-Roger

THE STEARNS-ROGER MFG. CO. DENVER COLORADO

Tournarocker turns 90° in 12'4" radius, spots fast despite restricted quarters on quarry ledge . . . with 5 to 6 passes from loader gets 7 heaped yds. in 2 to 3 min.

At hopper, Tournarocker dumps entire load in average of 15 seconds. Rig operates 10 hours per day, 6 days per week, supplies 100% of Olaton crusher requirements.

this application whips tight quarters of Kentucky pit

Fort Hartford teams D Tournarocker with front-end loader

To speed limestone delivery from a new hillside quarry to their crusher at Olaton, Fort Hartford Stone Quarry of Hartford tried teaming a highly-maneuverable D Tournarocker with a 1¼-yd. front-end loader. This team worked so successfully in the cramped quarters of the quarry ledge, that the 9-ton "D" now supplies 100% of crusher requirements. Here's typical production:

52½ bank yds. hourly on 300′ haul

With 7′ loading height and low rear entry, Fort Hartford's Tournarocker is heaped with 7 yards of shot rock in 2 to 3 minutes. Short 300′ one-way haul to crusher takes only 20 seconds . . . dump, return, and spot, from 1 to 1½ minutes . . . complete 600′ cycle, 4 minutes. Output per 50-minute hour averages 12½ loads or 52½ bank yards (40% voids). To minimize spotting time in the highly restricted loading area, the mobile, electric-control Rear-Dump unit turns 90° within a radius of 12′4″.

"Thoroughly sold," says President

"We're thoroughly sold on the Tournarocker," says A. C. Hall, President of Fort Hartford. "It maneuvers well on our works where tight quarters are the general rule. We like it very much." The Company, a subsidiary of Fort Hartford Coal Company, also uses their "D" to haul overburden. Their year-around operation clearly demonstrates that the 9-ton D Tournarocker can be profitably loaded with small front-end loaders.

To find out how versatile rear-dump Tournarockers can add to *your* profits, have your LeTourneau Distributor show you owner-verified reports on work similar to your own. Ask him how Tournarocker's many revolutionary features can help increase your production . . . provide greater operating safety . . . and lower maintenance costs. There's a size to fit your needs . . . 9, 18, 35, or 50 tons.

High-speed, rubber-tired excavating hauling • lifting equipment

R. G. LeTOURNEAU, INC., Peoria, Illinois

7′ loading height and low rear entry speed loading . . . 3-ply steel-grid bowl takes shocks of loading big-chunk limestone, requires minimum patching and welding.

Hauling from pit to crusher, Tournarocker's 4-wheel Multi-disc air brakes provided sure control at all times. Unit safely worked over 16% grades while stripping overburden.

"IRON for iron" may soon be the primary concept of Mexico's mining industry. If reports that President Adolfo Ruiz Cortines intends to extend federal control over mining are true, Mexico will export iron ore to the U. S. only in return for machinery. Actual exporter will be the Federal Government, with negotiations through the Bank of Mexico. Shipments of iron ore, under this kind of arrangement, can be tightly controlled, assuring that machinery and heavy equipment instead of dollars are the means of payment. Expansion of this policy in the next few years can be expected according to reports.

The National Association of Mining Associations of Small Operators is pressing the Government for creation of a new state department in charge of technical administrative and fiscal aspects of the industry as a whole. A plan for a basic project was submitted to President Cortines. Causes retarding the development of industry were listed as the natural exhaustion of the mines, and a "mistaken fiscal policy" which is "squeezing" investments. The Department of Treasury and Public Credit named a joint commission comprising official technicians and members of mining associations to search for answers to the problems. Special attention is being paid the small operator. However, some observers simply comment that the present *ad valorem,* or production tax, is prohibitive to all but the richest operations.

Plans are reported in progress for the State of Oaxaca. It is expected that large scale exploitation of gold, silver, iron and tungsten mines will take place in the near future. The greatest need is for smelters and ore processing plants. Outlays for a plant capable of handling even 25 tons of ore per day stopped many a small operator in the past.

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ASSUMING that one day a lasting peace comes to Korea, although history since the Khans denies the possibility, the country faces one of the toughest economic hurdles in the world. Only tungsten mining shows signs of strength. The U. S. has contracted to buy all of Korea's tungsten production and in a few years the Koreans will be supplying a sizeable part of the world's supply. But tungsten alone cannot form the base for a well-entrenched economy, and minerals are the basis for fiscal well-being in any nation.

United Nations surveys indicate that Korea will need some 2 million metric tons of coal exclusive of industrial requirements. All coal found in South Korea is anthracite, lacking in cohesiveness and breaking easily into powder. But this is the stuff with which the Koreans must work. Known anthracite reserves are estimated at 100 million tons, with the possibility of additional deposits. Before the coal can be used it must be briquetted. In 1949 330,000 metric tons of briquettes were produced compared with an estimated 50,000 metric tons in 1952. No lignite was produced in 1952 and bituminous imports rose to one million tons against 660,000 metric tons in 1949. Korean coal production is well under civilian requirements. Mines and properties for development exist, men to work the mines are available, but working capital is not.

Japanese occupation forces gutted many mines in an attempt to get all they could, without respect to economic values. Many of the Japanese-operated mines are closed. However, production of many of the minerals found in Korea, gold, silver, tungsten, graphite, bismuth, molybdenum, talc, kaolin, lead, copper, manganese, and others, continues on a limited basis during hostilities.

All reserves are government-owned. In the opinion of UN observers, disposal to private investors would create strong incentives. Future planners must recognize the importance of Korean mining in the nation's revival. Aid programs in the past have tended to accent the farmer rather than the miner.

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THE sea may someday be the source of the world's minerals. Bruce M. Gonser, assistant director of Battelle Memorial Institute, recounts fascinating pieces of information of the behavior of sea life in relation to the minerals found in the water. Someday this behavior may offer scientists starting points for reclamation of many minerals no longer mineable on land.

Shellfish use strontium carbonate to build homes. Diatoms employ silica for their skeletons. Lobster and mussels remove cobalt from the sea, and the blood of ascidians and sea cucumbers have been found to contain vanadium. Various mollusks extract nickel from the sea and concentrate it in their bodies. King crabs, despite the scarcity of copper in the sea, extract the metal and use it much in the way that humans use iron.

Potassium and iodine have been extracted from sea weed in appreciable amounts and magnesium from sea water is assuming importance in mining. Even more concrete evidence that minerals can be successfully taken from the ocean is the work of the Billiton Mining Co., in the Netherlands East Indies. Billiton is dredging tin from the ocean floor 100 ft below the surface. The dredges operate as far as 12 miles offshore. Mr. Gonser reports that a British firm is using a nonrigid or grab-bucket type dredge, going to even greater depths.

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STABILITY of a sort has entered the copper market, but no one is willing to predict the length of time it will last. Several disturbing factors may upset what some experts feel is the rapidly approaching balance between supply and demand. Britain announced it will drop import and distribution controls held on copper since World War II. European consumption declined during the first quarter of 1953—resulting in surpluses in Britain. Current offers from several foreign sources are on the upswing in the U. S. It may be recalled that U. S.

lead-zinc prices fell when those metals were decontrolled by Britain. Huge amounts were *dumped* on the markets as Britain's surplus sought to find an outlet. Significant amounts of Northern Rhodesian copper may find its way to American markets because of the lack of a European market of any proportions. The Continent was the chief buyer for Northern Rhodesian copper until recently.

Development of Northern Rhodesian copper began with the discovery of the metal by W. C. Collier in 1902. He shot a buck antelope at the site of the present Roan Antelope mine. While examining the horns Collier noticed streaks of copper in the rock where the animal lay. Actual development did not start until the nineteen twenties. Three other mines, Nkana, Mulfulira, and the Nchanga, followed. Today an area about 65 miles long and half as wide is the world's third largest copper producing section.

If Northern Rhodesian copper enters the U. S. market, it will do so on an important competitive basis for the first time. The belt is interesting in many respects. Much of the racial unrest typical of Africa today has been avoided in Northern Rhodesia because of what must be termed an enlightened policy. Compared to the rest of Africa, wages are good, sanitation and living conditions respectable. American Metal Co., holding large interests in the Roan Antelope and Mulfulira mines, announced that operating companies for those mines requested the Northern Rhodesian Copper Miners Union to alter work contracts to allow Africans to advance to more responsible positions.

The Copperbelt is a low cost, efficient operation. However the biggest problem is a recurrent one—lack of coal. Recently, the shortage was so acute that Mulfulira operated at half capacity. Hundreds of men are kept busy cutting wood to supplement fuel for power plants and smelters.

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IRON ore from Orinoco Mining Co.'s Cerro Bolivar development in Venezuela is scheduled to roll toward the U. S. early in 1954. Trucks will haul ore to trains waiting halfway down the slope. Ninety-one miles later at Puerto Ordaz on the Orinoco River, the ore will be unloaded into ships bound for U. S. Steel Co. mills via eastern seaboard ports. So will begin an operation growing out of aerial photographs taken in 1947 showing promising rock formations in the Cerro Bolivar area.

The first party to reach the mountain was literally surrounded by rich outcroppings. Orinoco, U. S. Steel subsidiary, has been developing the property ever since. The big problem has been transportation. There was no road to a port which did not exist. Roads needed building, railroad tracks had to be laid, a port dredged out of the river bottom, and docking facilities installed.

Today more than half the railroad track is on the ground. A 34 ft channel is being dredged from the mouth of the Orinoco to Puerto Ordaz. The port itself is literally carved out of the shoreline. Docking facilities are under construction, along with crushers, mixers, and loading facilities.

Some 500 million tons of rich ore lies waiting on the Cerro Bolivar property. Benjamin J. Fairless, U. S. Steel chairman, predicts that 1.5 million tons of ore will be mined next year. Eventually, production may reach 10 million tons annually.

Cerro Bolivar is not the whole story of Venezuelan iron ore. Within a relatively short distance of Cerro Bolivar are other deposits which may yield as much ore as the spectacular mountain. Transportation facilities serving Cerro Bolivar may bring these additional deposits into reach. Other American steel interests are operating in Venezuela.

Venezuelan Government officials estimate government-owned properties hold an additional one billion ton reserve. These properties are near enough to Cerro Bolivar to take advantage of roads, tracks and rolling stock installed by Orinoco. The Venezuelan Development Corp., a government agency, wants to build a 70,000 ton-a-year steel mill despite the country's coal poverty. Use of low grade coal is contemplated.

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OVER the years many plans have been proposed, but American colleges and universities still face tremendous financial problems. Schools require money to train the men needed to continue American leadership in world industry. Many a good lad fails to get to college because the money just isn't there. It's tough to work one's way through school when dollars are needed for basic necessities of the family. Short of Federal subsidization, which many college heads reject, the only answer seems to lie in the direction of increased aid through wider distribution of scholarships. Industry cries for engineers—and the colleges turn out fewer each year. While a good part of the reason lies with the personal choice of the student—many just can't afford to travel the road of science curricula.

Lately, business has been thinking of lending a hand to the nation's schools. But college deans and presidents have viewed the idea with about the same attitude held toward Government aid. One question arises: "What are the strings?"

Bethlehem Steel Co. answered the question recently. Instead of the direct scholarship or subsidization for a specific purpose approach, the steel company offered 45 private institutions $3000 for each graduate hired for Bethlehem's training course—and who stays four months.

The money can be used as the schools see fit—"for scholarships, or any other purpose which best meets their needs." Eugene G. Grace, Bethlehem chairman, points out that "four years of college costs a college more than it receives from a student in tuition and other fees, and that the college graduate's education makes him a valuable asset in the conduct of Bethlehem's business."

Estimates of program cost place it at a possible $300,000 per year. While Bethlehem is primarily interested in engineering students, the firm is looking for men to fill positions in other departments.

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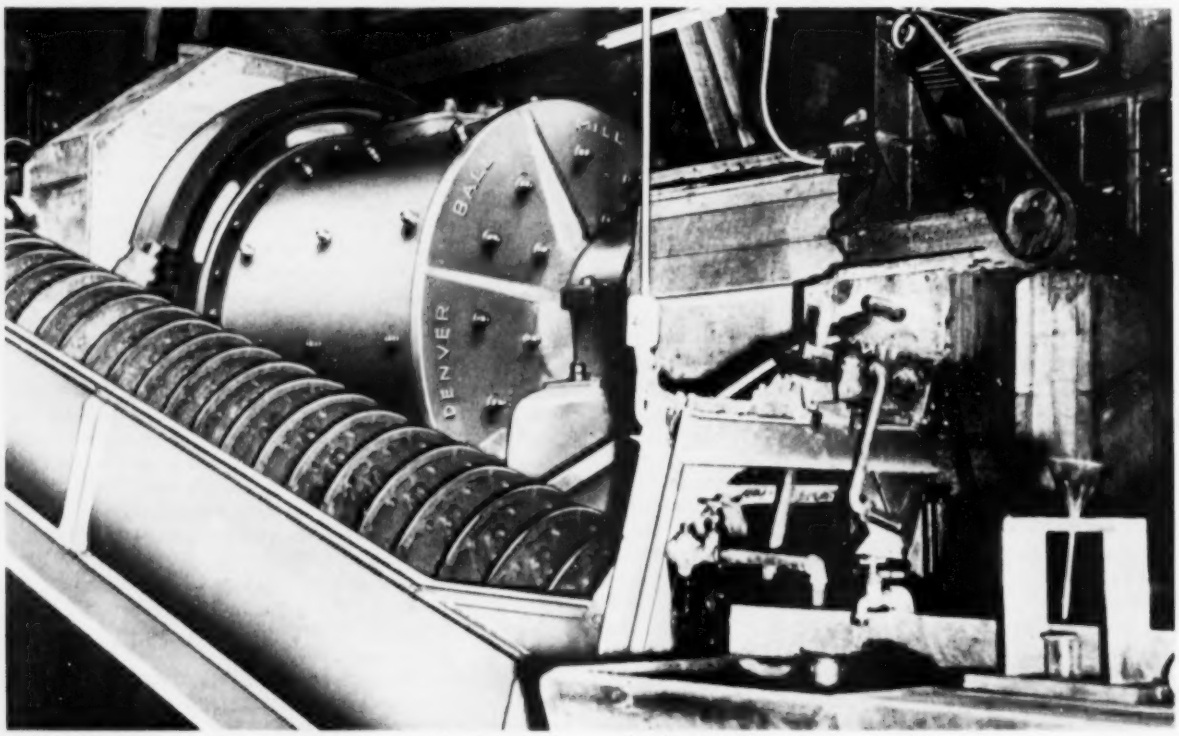
Complete Milling Equipment—from testing, to feeder, to dryer!



This 5'x5' Denver Steel-Head Ball Mill, operating in a lead-zinc, gold-silver mill, shows the heavily reinforced steel head. Because of the crack-proof Denver Steel Heads and the long-wearing bearings, mill men depend on Denver Ball-Rod Mills for years of service. A No. 250 Unit Flotation Machine is pictured on the right.

Eliminate Shut-Downs Caused By Cracked Heads, Use Denver Steel-Head Ball-Rod Mills

Many years of continuous, high production with minimum maintenance and repair are possible with Denver Steel-Head Ball Mills. Because of the specially constructed steel heads in all Denver Ball-Rod Mills, the danger of cracking a mill head has been eliminated. Steel is the best insurance against cracked heads and resulting mill shut-downs. Your profits are greater because of the dependable, continuous service you get from Denver Ball-Rod Mills.

CRACK-PROOF STEEL HEADS

By using tough steel, four times stronger than ordinary cast iron, not one Denver Steel Head has ever been reported cracked. The steel heads are electric welded to a steel shell, giving you all-steel construction throughout (bolted steel construction is also available).

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Denver Steel-Head Ball Mills are completely assembled and then the trunions are turned in a big lathe, making trunions absolutely true and accurate.

This accuracy makes bearings wear longer because the weight is evenly distributed over the entire bearing surface — giving lower pressure per square inch of bearing surface. Evenly distributed wear permits efficient use of babbitted bearings and eliminates ball and socket joints.

Write or wire today. Find out how these and many other advantages of Denver Ball-Rod Mills give you more dependable service and increase profits.

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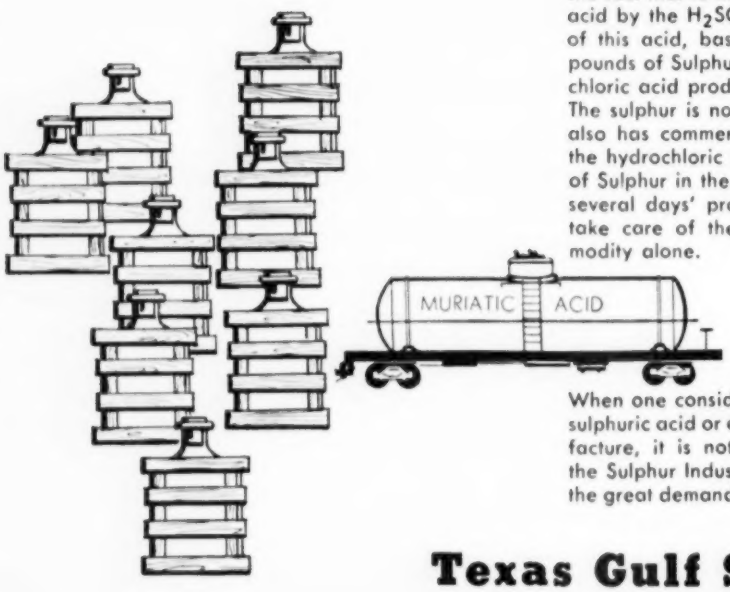
PARAPHRASING an old saying: 'It takes a chemical to make a chemical,' certainly applies to hydrochloric acid.

No chemical engineer has to be told how hydrochloric acid is made but sometimes with the mind focussed on the word "hydrochloric" little thought is given to another word "sulphuric." It is this word that calls attention to the fact that to make one net ton of 20° Bé hydrochloric acid by the H_2SO_4 process requires about 950 pounds of this acid, basis 100%, which is equivalent to 320 pounds of Sulphur. About one third of the annual hydrochloric acid production is made by the use of sulphuric. The sulphur is not lost because salt cake, a by-product, also has commercial value. But any way you figure it, the hydrochloric acid industry is an important consumer of Sulphur in the form of sulphuric acid. In fact, it takes several days' production from all the Sulphur mines to take care of the annual production of this one commodity alone.



When one considers all the other chemicals that require sulphuric acid or other Sulphur compounds for their manufacture, it is not difficult to appreciate how faithfully the Sulphur Industry is serving industry today in spite of the great demands made upon it.

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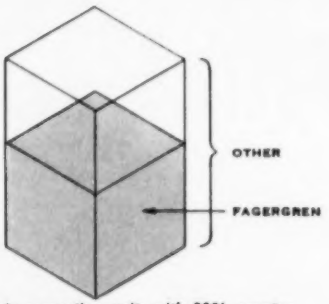
WITH LESS **TOTAL** CELL VOLUME!



1. *Compared to competing units with 80% greater total cell volume*
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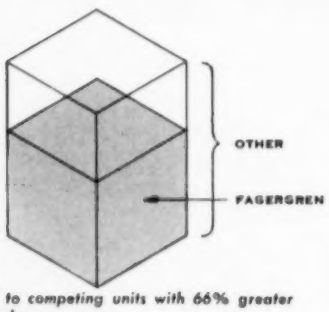

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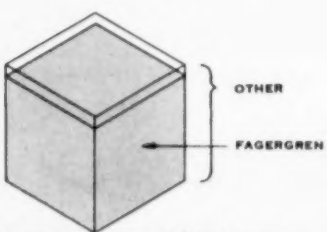

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These test results prove Fagergren superiority

- The figures shown here are the results from extensive tests recently conducted by a large mining company. They graphically illustrate that Fagergren Flotation Machines out-perform other machines having as much as 80% more total cell volume. Note also that when the total cell volume of Fagergren units and other machines is more nearly equal, the advantages of Fagergren operation are even more pronounced. These results and other related tests prove conclusively that in terms of lower tailing losses, higher concentrate grade, lower reagent costs and lower smelting charges, Fagergren machines are superior on every count.

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Drift of Things

DURING the last week in April, cards were sent out from New York to Institute members affiliated with the Mining, Geology, and Geophysics Div. The cards requested recipients to indicate their main technical interest within the division, i.e., mining, or geology, or geophysics. The reason for the cards is simple. Within the Institute more than 8000 have expressed either primary or secondary interest in this division. However, there is no way to determine the technical association stimulating this interest.

With presentation of this choice, information heretofore unavailable is being assembled. For instance, an MGGD officer requests the number of geologists, geophysicists, and miners in the division or names of members who are geologists, or geophysicists, or miners, only to get a negative answer. Compilation of the data on the returned cards will eliminate the problem. If new and younger people are to be drawn into active participation in divisional affairs, it is necessary to know their technical activity and what they can do.

These cards will be utilized to adjust Institute files and addressing system. In the future, the coding given on page 233 of the 1953 AIME Directory will have its full significance. At one time, the code letters "I" and "L" were kept on the records, and it was possible to determine technical interests. Following the formation of the Mining, Geology, and Geophysics Div. in 1949, this was dropped. Now it is apparent that the division is rapidly becoming inoperative because of these omissions.

In addition, this mailing is clearing the records of members who don't realize they are connected with MGGD.

Maintaining a record of technical interests for the members of MGGD will serve as a stimulant to the largest division in the Institute, and aid in building better programs and meetings for the Mining, Geology, and Geophysics Div.

MIXED reaction was received when the Institute Board of Directors voted last February to halt the All-Institute Fall Meetings, but the mining divisions have taken the "bull by the horns" and come up with four live-wire meetings to offset any possible loss. It looks as if AIME members will have a very full fare this summer, wherever they reside, or wherever they vacation, with meetings at El Paso, Hibbing, Chicago, and Ingonish, Nova Scotia.

Minerals Beneficiation Div. is preparing for a first-rate gathering on the Iron Range. The Minerals Beneficiation Sub-section of the Minnesota Section will be hosts to the division at Hibbing, August 31 through September 2. Field trips will dominate the meeting. There will be one half day of technical papers covering Iron Range developments.

Industrial Minerals people are going to have a vacation meeting at the Keltic Lodge, Ingonish, Nova Scotia, September 8 through 13. Along with the Ind. Min. Div. of the Canadian Institute of Mining and Metallurgy, the AIME group will be guests of the Mining Society of Nova Scotia. The program for this meeting and general information has been appearing in MINING ENGINEERING.

Mining, Geology, and Geophysics Div. will hold a Fall Regional Meeting in conjunction with International Mining Days at El Paso, Texas, October 28 through 31. Industrial Minerals Div. will also participate on a local basis. Plans include four technical sessions, numerous field trips, and social events galore such as can be found only in the southwest. Sunshine is standard equipment in this area, not to mention that Mexico's Cuidad Juarez is only five minutes from downtown El Paso.

The Coal Div. will have its regular fall gathering in the form of the Joint Fuels Conference, scheduled for Chicago, October 28 to 30. This is the meeting that brings the miner and the consumer together to discuss common problems. This will be a joint meeting with the American Society of Mechanical Engineers.

WE were very fortunate to be able to attend the 1953 Coal Show in Cleveland May 11 to 14, with its huge display of new equipment. It was fascinating to see how many new pieces of equipment have been designed and built for coal mine mechanization. In spite of the friendly-negative attitude the metal miner has toward the coal miner, and *vice versa*, it was astonishing how many of the materials-handling devices built especially for coal mines would actually be just as useful in "hard rock" operations. During the coming months we will try to pass some of these ideas along to you through the pages of ME.

ON the next page (576) is the first real story of the much discussed pressure-leach process for copper, nickel, and cobalt. Through the pages of MINING ENGINEERING we are giving you the complete tale of the development of Sherritt Gordon's refinery and its process. On the pages following this article is the story of Sherritt Gordon's move from Sherridon to the new mine at Lynn Lake. This revelation may be the key to future developments as nonferrous mining tackles tougher ores, and turns to lower grade ores.

AND here is an item from *Journal of Metals* which warrants consideration:

A distinguished visitor from London, whose name we are not permitted to mention, related this story at a recent luncheon. One morning, at a home in a somewhat remote and primitive area, the privy was found in the river that flowed beside the house. The father of the house demanded to know if his son had pushed the privy in the river during the night. "No sir," replied the son. The father then proceeded to relate the story of George Washington and the cherry tree, closing with, ". . and George Washington, having told the truth, was not punished." After the story, the father repeated his question, and the son replied, "Yes father, I pushed the privy in the river during the night." At this, the father began to thrash the son severely. "But father," he cried, "you said George Washington wasn't punished when he told the truth!" "Yes," replied the father, "but George Washington's father wasn't in the cherry tree when it was cut down either!"

Charles M. Cooley

Ammonia or Acid Leaching Combined with Hydrogen Reduction Finds Wide Application

Over the past year details were released on a hydrometallurgical process for recovering pure metal from sulphide concentrate. **Chemical Construction Corp.** played an instrumental role in the development of this process. First details were revealed by MINING ENGINEERING in May 1952.

Five plants in three countries in various stages of planning, construction and operation testify to the rapid strides of the process. **Howe Sound Mining Co.** has a cobalt refinery coming into operation at Salt Lake City to treat concentrates from Calera, Idaho. In this $2.5 million plant an acid leach precedes cementation of copper, and cobalt precipitation by hydrogen under pressure. This process parallels that proposed for **National Lead Co.'s** $5 million plant being built at Fredericktown, Mo. to treat 50 tons per day of cobalt-nickel-copper concentrate. More recently, spokesmen of **Freeport Sulphur Co.** disclosed that Chemico's process for "the production of nickel as a metal rather than oxide, and also of cobalt" will be combined with Freeport's sulphuric acid leach to treat ore from the recently discovered Moa Bay nickel deposit in Cuba. **Sherritt Gordon's** refinery in Alberta will also use Chemico's metal precipitation technique, combined in this case with Sherritt's ammonia leach.

Chronology of Sherritt Gordon Process Development

1946 Lynn Lake mine development under way—Sherridon mine exhaustion in sight.

1947 Laboratory work initiated to develop a hydrometallurgical process for nickel sulphide concentrate.

1948 Ammonia leach process found promising. 50-ton per day pilot mill produces nickel concentrate for process study.

1949 Chemical Construction Corp. joins research effort and supplies a nickel precipitation method. First pilot plant built.

1950 Second pilot plant built incorporates nickel precipitation equipment.

1951 Third pilot plant with 3000-lb per day capacity provides design data for commercial plant.

1952 Construction of commercial refinery begun at Fort Saskatchewan. 2000-ton Sherridon concentrator being moved to Lynn Lake.

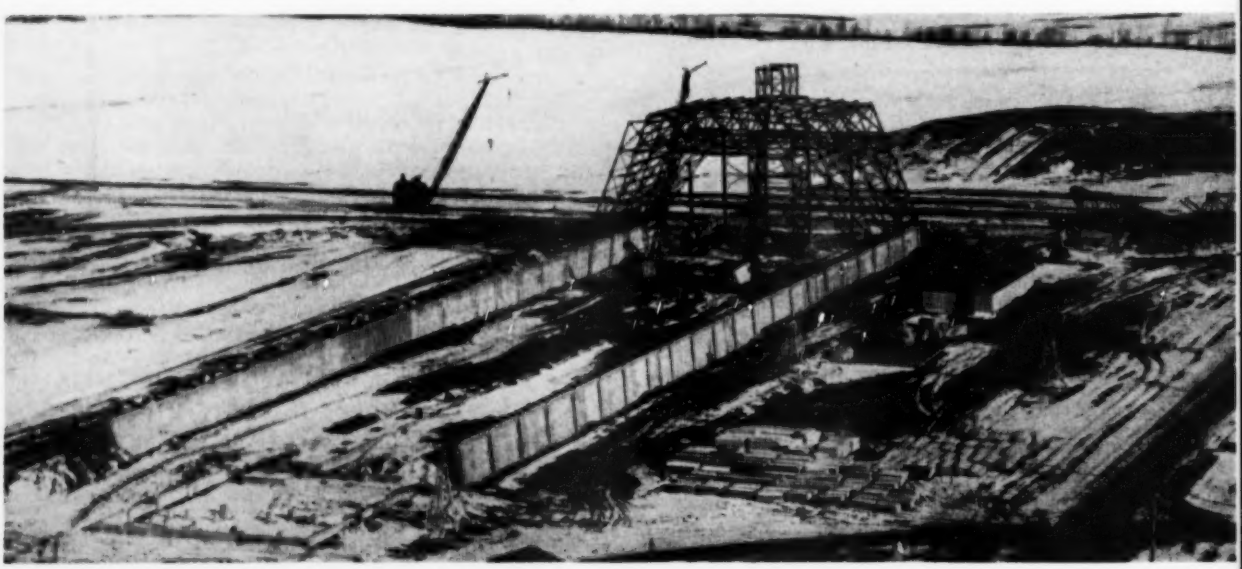
1953 Fourth pilot plant provides further research and trains key personnel. Production at Lynn Lake mine scheduled to start by end of year.

1954 Fort Saskatchewan refinery and chemical plant scheduled to start operation January 1.

Sherritt Gordon

Uses Ammonia

REFINERY—Steel rises at Fort Saskatchewan, near Edmonton, Alberta, for Sherritt Gordon's new plant, first in Canada to use ammonia pressure leaching. Chemical Construction Corp. is the consultant, and their Canadian affiliate, Chemical Construction (Inter-American) Ltd., has design and construction contract on ammonia and metallurgical plants. Present schedule calls for start-up in January 1954.



PILOT PLANT — Final leach autoclaves can be seen in foreground of this view. In the center is the adjustment leach autoclave, with the stripping autoclave at the rear. At the extreme right is the adjustment thickener. Wetted surfaces of autoclaves, agitators, pumps, valves, tanks, and pipelines are of stainless steel.

Leach for Lynn Lake Ni-Cu-Co Sulphides

Here are the details . . . . . of how a $2.5 million research gamble, now backed by five years of intensive development in cooperation with the Chemical Construction Corp. resulted in a hydrometallurgical process that yields pure metal powders from sulphide concentrate — a process that offers potential savings of $2.5 million a year.

SHERRITT GORDON is building a refinery at Fort Saskatchewan, Alberta which will employ a hydrometallurgical process for treatment of Lynn Lake nickel sulphide concentrate at a saving of $2.5 million per year. The refinery, which will produce nickel and cobalt metal powders as well as ammonium sulphate, is the culmination of research involving Sherritt Gordon Mines Ltd. and the Chemical Construction Corp. in four pilot plants over a period of five years.

In 1947 Sherritt Gordon was developing a new mine at Lynn Lake, Manitoba. The company's operating property at Sherridon was rapidly nearing exhaustion. Preliminary work suggested that a hydrometallurgical process might overcome some of the drawbacks of conventional smelting of the nickel flotation concentrate to be produced at Lynn Lake, successor to Sherritt Gordon's Sherridon operation. Declining reserves at Sherridon, however, forced a five-year deadline on process development.

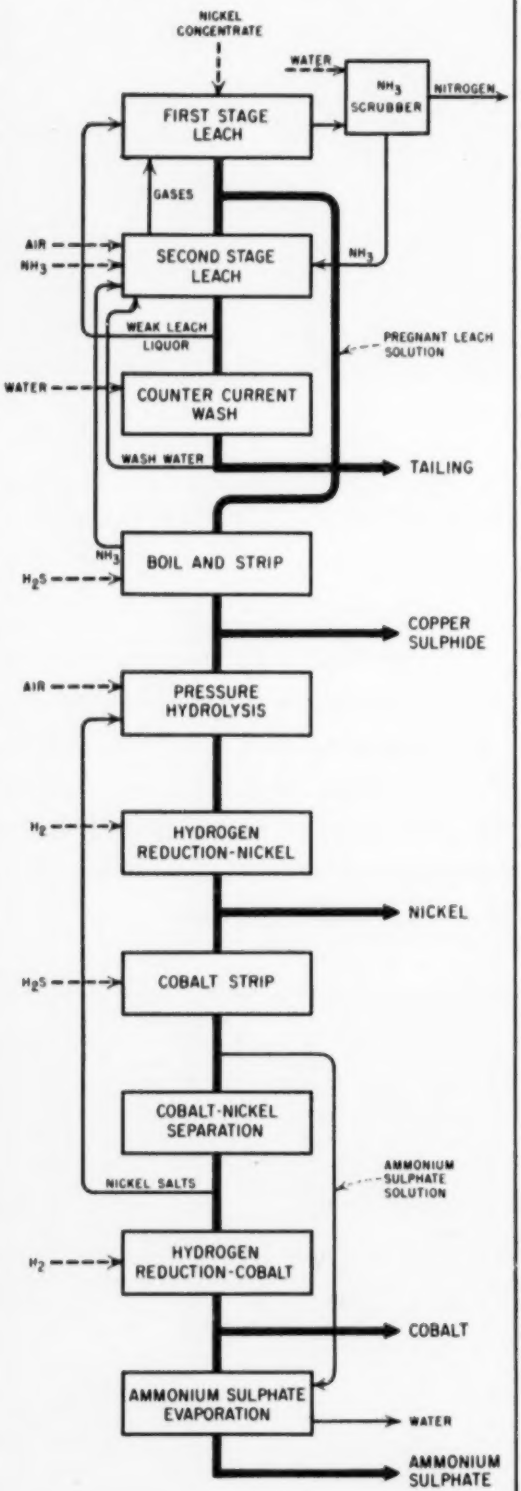
Five years and four pilot plant stages later Sherritt Gordon was able to finalize refinery design and began moving the 2000-ton concentrator from Sherridon to the new property at Lynn Lake, 150 miles farther north in Manitoba. Ore reserves developed at Lynn Lake amounted to 14 million tons carrying 1.223 pct nickel, 0.618 pct copper and some cobalt. Near Edmonton, Alberta, the nickel-cobalt refinery and chemical plant began to rise from the prairie.

Flotation testing of Lynn Lake ore readily produced a 30 pct copper concentrate and a nickel-cobalt concentrate with some copper content. Treatment of the copper concentrate by conventional smelting appeared economical. Nickel and cobalt recovery from the second concentrate presented more of a problem.

Conventional smelting and electrolytic refining for the nickel sulphide concentrate offered an estab-

Information for this article was largely supplied by Professor F. A. FORWARD, pioneer in the development of ammonia leaching techniques. Professor Forward is Head of the Dept. of Mining and Metallurgy at the University of British Columbia, where much of the research that laid the groundwork for the present process was carried out. He presented a paper, *Leaching Nickel-Copper-Cobalt Sulphides with Ammonia Under Pressure* at the 1953 Annual General Meeting of the Canadian Institute of Mining and Metallurgy.

FLOW SHEET OF AMMONIA PRESSURE LEACHING PROCESS FOR TREATING NICKEL-COPPER-COBALT CONCENTRATE



CHEMICAL REACTIONS

Unique in that nickel, cobalt and copper are extracted and recovered separately from a sulphide concentrate by hydrometallurgical operations only, the chemical foundations of the process lie in the equations given below:

Ammonia Leaching—Ammonia, oxygen and water react with the sulphide in an autoclave at 125 psi and 150° to 220°F to yield metal amines, hydrated iron oxide and ammonium thiosulphate;

$$2NiS+8FeS+14O_2+20NH_3+8H_2O\rightarrow$$
$$2Ni(NH_3)_4SO_4+4Fe_2O_3xH_2O+4(NH_4)_2S_2O_3$$

and dissolved oxygen reacts further with the ammonium thiosulphate to produce ammonium sulphate and ammonium trithionate:

$$2(NH_4)_2S_2O_3+2O_2\rightarrow(NH_4)_2S_3O_6+(NH_4)_2SO_4$$

Further oxidation of the trithionate produces more ammonium sulphate and ammonium sulphamate:

$$(NH_4)_2S_3O_6+2O_2+4NH_3+H_2O\rightarrow$$
$$NH_4SO_2NH_2+2(NH_4)_2SO_4$$

At the end of the second leaching stage the hydrated ferric oxide, silica and insoluble compounds are filtered, washed and discarded. The two stage continuous counter current leach is carried out in a continuously operated compartmented autoclave. The first stage treats fresh concentrate with recycle liquor from the second stage and the partly leached solids go to the second stage where they are supplied fresh ammonia. Oxygen demand is lower in the second stage and increasing amounts of sulphate and sulphamate are formed.

Copper Removal—Boiling in a continuous still removes excess free ammonia and decomposes thio-

lished procedure, predictable operating results, and known design factors. Smelting would recover any gold and silver as well. On the other hand, costs would be high for labor, materials and power, especially in a remote area such as Lynn Lake. Precious metal content of the ore is less than 0.02 oz per ton and smelting would lose a major part of the cobalt.

Hydrometallurgical methods for recovering the nickel and cobalt promised to simplify materials handling, eliminate any dust problem, and instrumentation and automatic control in a hydrometallurgical plant would reduce required labor force.

Examination of possible treatment methods for Lynn Lake nickel-cobalt concentrate was undertaken in 1947. Within a year F. A. Forward and workers at the University of British Columbia found an ammonia leach that would do the job. Following early laboratory flotation testing a 50-ton per day pilot mill was set up at Lynn Lake that eventually provided over 350 tons of nickel concentrate for leaching studies. Work on this concentrate showed that nickel, copper, and cobalt sulphides could be dissolved without roasting if the proper temperature and pressure and concentration of oxygen and ammonia was maintained. The next step was development at the University of British Columbia and in Sherritt Gordon's laboratory at Sherridon of a means of separating the metals and the ammonium salts from the leach solution.

BEHIND THE FLOWSHEET

sulphate and trithionate as follows:

$$S_2O_6^{--} + Cu^{++} + 2H_2O \rightarrow 2SO_4^{--} + CuS + 4H^+$$
$$S_2O_3^{--} + Cu^{++} + H_2O \rightarrow SO_4^{--} + CuS + 2H^+$$
$$8Cu^{++} + 2S_2O_3^{--} + 4H_2O \rightarrow 8Cu^+ + S_2O_6^{--} + SO_4^{--} + 8H^+$$
$$2Cu^+ + S_2O_6^{--} + 2H_2O \rightarrow Cu_2S + 2SO_4 + 4H^+$$

Insufficient sulphide ion is produced to precipitate nickel, and the copper sulphide contains only about 1 pct nickel while the purified solution contains less than 0.005 g of copper per liter. While all the copper may be precipitated by the reactions above, it is convenient to remove the last traces of copper with small amounts of H_2S.

Hydrolysis—After removal of copper through the reactions above, remaining thionate and thiosulphate and sulphamate are removed to avoid high sulphur content in the nickel metal product. Oxidation under pressure converts the thionate to sulphate and hydrolyzes the sulphamate:

$$S_2O_6^{--} + 2O_2 + H_2O \rightarrow 2SO_4^{--} + 2H^+$$
$$S_2O_6^{--} + 2O_2 + 2H_2O \rightarrow 3SO_4^{--} + 4H^+$$
$$NH_2SO_2NH_2 + H_2O \rightarrow (NH_4)_2SO_4$$

Hydrogen Reduction—As shown by the reactions below, both cobalt and nickel compounds react the same way when treated with hydrogen under pressure:

$$Ni(NH_3)_2SO_4 + H_2 \rightarrow Ni^\circ + (NH_4)_2SO_4$$
$$Co(NH_3)_2SO_4 + H_2 \rightarrow Co^\circ + (NH_4)_2SO_4$$

Separate nickel precipitation, leaving cobalt in solution, is possible because the nickel reaction proceeds more readily. To minimize cobalt precipitation due to overlap of reaction conditions about 1 g of nickel is left per liter of solution.

Two separate streams of research came together in December 1948, and out of their junction the present process was evolved. Chemical Construction Corp. was brought in to discuss engineering and design of a pilot refining plant. Independently, Chemico had been studying pressure leaching of sulphide ores with acid solutions. More important, they had discovered a means of nickel precipitation from ammoniacal solutions by using hydrogen under pressure.

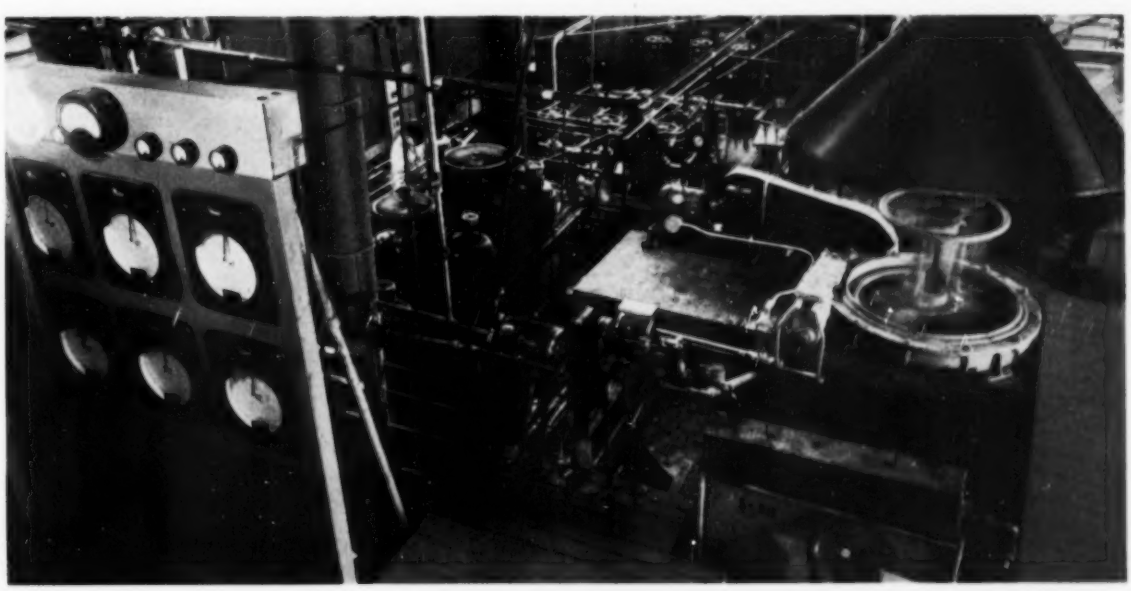
Chemico's precipitation step vastly simplified metal production from the leach solution. When these two steps were brought together the final process began to take form; an ammonia leach as developed by Sherritt Gordon, followed by Chemico's pressure hydrogen precipitation procedure to recover nickel and cobalt metal from the solution.

Four Pilot Plants

Hydrometallurgical treatment of Lynn Lake nickel sulphide concentrate represents a long chain of work, a gradual scale-up of development stages. The third pilot plant provided data for design of the Fort Saskatchewan refinery, but research has not ceased and a fourth pilot plant now in operation embodies every stage of the full size plant now under construction. Complete instrumentation provides an opportunity for continuing study and a training ground for future operating personnel. In the words of C. A. Hames, manager of the metallurgical research div., ". . . the main objectives being to define the range of possible operating conditions and at the same time to train key personnel. . . It is hoped . . . the initial difficulties and adjustments of starting up the metallurgical plant will be minimized."

Cornerstone of any research program is adequate and representative testing material. In this case construction of a 50-ton per day pilot mill at Lynn Lake followed up early laboratory flotation testing.

Leaching tests at the University of British Columbia in 1947 and 1948 outlined a nickel recovery method that involved roasting, hydrogen reduction and leaching with ammonia and ammonium carbonate. During this work the basis of the present process was laid by discovery that under proper



Ammonia leaching section of pilot plant. Note recording instruments at left. Sherritt Gordon's leach-reduction process uses ammonia leach which dovetails with hydrogen reduction step, that is carried out in ammoniacal solution.

These are the Figures———

Analysis of Flotation Concentrate Produced in the Pilot Mill

Nickel	10 to 14 pct
Copper	1 to 2 pct
Cobalt	0.3 to 0.4 pct
Iron	33 to 40 pct
Sulphur	28 to 34 pct
Insoluble	8 to 14 pct
Precious metals	less than 0.2 oz per ton

This nickel-cobalt concentrate appeared to give the best economic return, and was the material upon which process studies were based.

Recovery by Leaching, Based Upon Treatment of Flotation Concentrate

Nickel	90 to 95 pct
Copper	88 to 92 pct
Cobalt	50 to 75 pct
Sulphur	60 to 75 pct

Sulphur is recovered in the form of saleable ammonium sulphate.

Analysis of Metal Products, Pct

Nickel*		Copper Sulphide		Cobalt**	
Ni+Co	99.95+	Cu	70.0	Co	99.6
Co	0.10	S	22.5	Ni	0.15
Fe	0.01	Fe	1.5	Fe	0.20
S	0.01	Ni	0.9	S	0.02
Cu	0.01	Co	0.06	Cu	nil
		H_2O	balance		

*Meets specification for electrolytic nickel.
**Purity higher than normal market specifications.

Analysis of Ammonium Sulphate Product and Leach Residue, Pct

Ammonium Sulphate		Leach Residue	
N_2	21.0	Ni	0.60 to 1.40
S	25.1	Cu	0.20 to 0.25
Ca	0.07	Co	0.12 to 0.25
Fe	0.01	Fe	42 to 52
Mg	0.004	S	9 to 15
Ni, Cu, Co	nil	Insoluble	12 to 16

control of temperature, pressure, and oxygen concentration, ammonia leaching of the nickel, copper and cobalt sulphides was possible without roasting and reduction treatment of the ore.

Next link in the chain of development was separation and recovery of the metals and ammonium salts from the leach solution. By December 1948 the first metal recovery method had been developed at the University of British Columbia and Sherritt Gordon's Sherridon laboratory. Nickel-ammonium sulphate was precipitated by boiling off ammonia and adding sulphuric acid. Precipitate was recovered by filtration. Further heating precipitated copper sulphide, and neutralization of the filtrate from the copper step precipitated cobalt sulphide. Ammonium sulphate was reclaimed from the end liquor by evaporation.

When the first pilot plant to employ the ammonia leach reached the planning stage, discussion was started with the Chemical Construction Corp. on engineering and design problems and since that time a close association has been maintained between the two companies on development of the ammonia leach-hydrogen reduction process.

The first pilot plant, built in quarters of the Mines Branch at Ottawa operated during the next 14 months. Vital data provided at this stage were the possibility of substitution of air under pressure for the oxygen used originally to oxidize the concentrates in the autoclaving operation and discovery of a means of copper removal from the leach solution. Control of process to provide high enough concentration of trithionate and thiosulphate ions followed by boiling at atmospheric pressure, precipitated copper sulphide enabling precipitation of pure nickel metal in a subsequent operation.

Simplicity characterized the first pilot plant, aimed primarily at study of leaching under continuous operation. In 1950 the second pilot plant was built on semi-commercial scale incorporating nickel precipitation with hydrogen in high pressure autoclaves. Scale-up data developed during six months operation of this plant guided design of the third pilot plant completed in 1951. This third pilot plant was equipped for two stage counter current leaching of 3000 lb of concentrate per day, utilizing continuous equipment for filtering, washing and ammonia recovery.

Intensive operation of this plant resulted in some 60,000 readings and 14,000 laboratory analyses. These provided design data for the commercial plant now under construction that will treat 235 tons of nickel concentrate per day.

Sherritt Gordon hasn't ceased research—the fourth pilot plant is providing further process study and training future operating personnel.

Sequence of operations planned for the Fort Saskatchewan plant and used in the fourth pilot plant breaks down into two stages, leaching and metal recovery. The second stage successively yields copper sulphide, nickel metal powder, cobalt metal powder, and finally a major part of the ammonia and sulphur introduced to the operation is recovered as saleable ammonium sulphate.

Two stage leaching and counter current washing of the concentrate take less than 24 hr in continuous operation carried out at about 125 psi and temperatures of 150° to 220°F. Sulphide minerals, ammonia, oxygen, and water reacting in the autoclave evolve more than sufficient heat to hold the leaching temperature. Amount of heat evolved, about 1500 Btu per lb of concentrate, is greater than that produced by roasting the same sulphide in air. Excess heat is carried off through cooling coils in the autoclaves. Wetted surfaces of autoclaves, agitators, pumps, valves, and tanks as well as the pipelines are of stainless steel. Corrosion and scaling have been of minor difficulty.

After filtering, the pregnant solution from leaching passes through a continuous still to remove any excess free ammonia. Boiling continues and the thiosulphate and trithionate decompose and copper sulphide is precipitated. Final traces of copper are stripped with H_2S. Purification of leach solution

prior to hydrogen precipitation of nickel consists of heating with air under pressure to oxidize any remaining thionate to sulphate and hydrolyze sulphamate to ammonium sulphate. Until such time as arrangements are completed to leach the entire copper concentrate production of the mine, the copper sulphide produced in the refinery will be shipped to a smelter. It will be uneconomic to leach the small amount of copper in the nickel concentrate, about 5 tons per day, and precipitate copper metal powder with hydrogen under pressure.

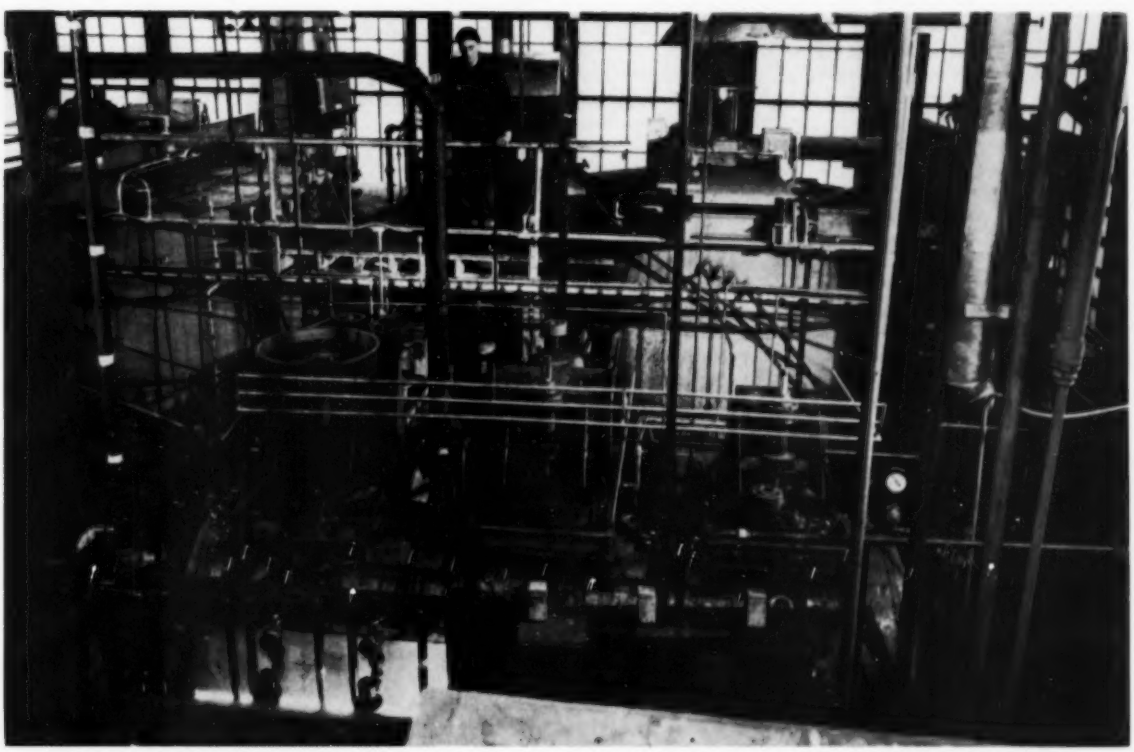
Nickel is reduced first, although the cobalt salts react identically, because the cobalt reaction requires more severe conditions. There is some overlap of the range of reaction of nickel and cobalt and about 1 g of nickel per liter of solution is left unprecipitated so that a minimum of cobalt comes down with the nickel. End product of hydrogen precipitation is a nickel metal powder composed of spheroidal particles in the 50 to 80 micron size range.

Following nickel precipitation the solution is treated with H_2S to precipitate cobalt and the remaining nickel. Stripped solution produces crystalline ammonium sulphate by evaporation. Nickel-cobalt sulphide is releached with ammonia and oxygen and the cobalt separated. The remaining nickel, separated as a soluble salt, returns to the nickel precipitation circuit. The cobalt produced by hydrogen reduction under pressure is a 99.6 pct cobalt metal in powder finer than 50 microns.

Overall operation is simplified by elimination of any dust problem, and the fact that all materials are handled by pumps for solutions, and blowers for gases. The only reagents are ammonia, water, steam, hydrogen and hydrogen sulphide. Reagent feed is automatic and interlocked automatic controls result in maximum process control with minimum labor force. Not least important to the economics of the operation is that most of the sulphur is converted to readily saleable ammonium sulphate. A major product of the plant, of higher value than cobalt or copper, ammonium sulphate puts Sherritt Gordon into the chemical business on a large scale in Canada's booming Alberta province. In the future the plant will probably see wide diversification of chemical production with possible output of ammonia, ammonium sulphamate, copper sulphate and several other products in addition to present planned production of pure cobalt and nickel metal powders and of ammonium sulphate.

Research costs money, especially where a multitude of problems are to be solved in developing a new process for a new mine. And, these problems are further heightened when the work must be pushed as fast as possible to meet a deadline. Including estimated expenditure for 1953, Sherritt Gordon has $2,508,000 invested in research behind the chemical plant that is to treat 80,000 tons of concentrate per year.

In its new hydrometallurgical process for treating Lynn Lake nickel concentrate Sherritt Gordon has a process that is under control of the company. The plant for metal reduction by all wet chemical operation will cost less than a combined smelting and electrolytic plant of equal capacity. Most important, the ammonia leaching process should net a saving over conventional processes of some $2.5 million per year, a saving great enough to recover the total projected research and development investment in one year.



This is a broadside view of the final leach autoclave in the pilot plant. Thickeners can be seen in the rear. The Fort Saskatchewan plant for metal reduction by all wet chemical operations, based on pilot plant experience, will cost less than a combined smelting and electrolytic plant of equal capacity, and offers savings up to $2.5 million a year over conventional plant.

Sherritt Gordon

Moves a 2000-Ton Concentrator —

And a Town — 165 Miles

by T. E. Burke-Gaffney

SHERRITT Gordon Mines transplanted a 2000-ton mining plant and concentrator along with a town and its people 165 miles into undeveloped and almost inaccessible country in shifting its base of operations to the new mine at Lynn Lake.

Faced with ultimate exhaustion of its ore bodies at Sherridon, Manitoba, the company, beginning in 1938, carried out an intensive program of prospecting and exploration in search of a new property. Late in 1945, diamond drilling of a magnetic anomaly near a minor surface expression of metallic sulphides gave promise of what has developed into the Lynn Lake nickel-copper deposit.

As development proceeded, it became apparent that the similarities, some of which were striking, between the new deposits at Lynn Lake and the old ones at Sherridon were more significant than the dissimilarities. It therefore seemed practical and economical to use the same plant for the Lynn Lake ore when operations at Sherridon were completed. The problem was then the unique undertaking of transporting the plant from the old site to the new.

Lynn Lake, inaccessible except by float-equipped aircraft and 120 air miles from the railhead at Sherridon, lay in entirely undeveloped country where up to one half the area was water-covered.

To carry out initial development at Lynn Lake, a supply line had been established. Sherritt Gordon had its own air transportation service, using standard bush planes. This was supplemented by the breaking of a 165-mile winter freight trail, 70 pct of which was over frozen lakes. This freight trail, which would have to be the means for transporting the plant, could be used but 2½ to 3 months of the year, for it was only through January to late March that the ice would support the loads carried. This road had been cut through to Lynn Lake during January and February 1946 and the winter of 1946-47 saw 2100 tons of materials and supplies hauled over this winter road to provide for the continuing exploration and development.

When it became evident that Lynn Lake would succeed Sherridon as the major mining operation of Sherritt Gordon, the big move was planned. The move had to be coordinated with the cessation of operations at Sherridon. Maximum continuous production and minimum gap in mining activity for Sherritt Gordon had to be dovetailed with activities outside the scope of this treatise, such as financing and marketing arrangements.

Assuring continued employment so that skills and experience would not be lost to the new undertaking was important. A smooth transition from production at Sherridon through dismantling and reconstruction to new production at Lynn Lake called for careful preparation and thorough planning.

The number 2 or East mine at Sherridon discontinued operations in 1946 when its ore was mined out. Dismantling started here the following year while production was maintained at the Main or West mine.

Total tonnage dropped from 600,000 to 400,000 tons per year, but because of rising copper prices the value of metals produced remained unchanged. Certain surplus crews were now directed into dismantling, and construction at Lynn Lake was providing the foundation on which the buildings and equipment would be set up again.

In anticipation of increased winter freighting, Patricia Transportation Co. was asked to submit tenders. The Patricia Co. had been engaged in Northern transportation for some years and they were familiar with the techniques and methods of winter freighting. They took over Sherritt Gordon's moving program in the winter of 1947-48 when 3000 tons were moved.

The winter of 1949-50 saw six houses moved from Sherridon to determine the feasibility of freighting out the town. Overland sections of the road had to be widened and techniques had to be developed for loading houses on special sleighs.

The season of 1950-51 was devoted chiefly to the transportation needs of the hydro-electric development 45 miles from Lynn Lake which Sherritt Gordon was building for the project.

During the short freighting months of these years, the techniques and methods for handling the move-

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ment of the mining plants, concentrator and town evolved, and nucleus crews were developed.

In the winter season of 1951-52 the main mining plant and concentrator and 73 houses were moved. Transplanting the plant required three steps: dismantling, moving, and re-erection. All the dismantling and re-erection with the exception of most of the structural steel work was done by Sherritt Gordon's own regular crew. Mining, milling and concentrating main plant ceased operations in September 1951. Most of the crews remained in their own departments to undertake dismantling, salvage, and preparation for shipment of their equipment and materials; others went to make up the house crews. The Dominion Bridge Co. had originally erected the structural steel and now undertook to dismantle and re-erect it.

Moving was all done by Patricia, using the original Sherritt Gordon equipment with substantial additions of its own. Thirty-six tractors and 200 sleighs manned and serviced by a crew of 150 men moved freight to Lynn Lake at an average rate of 200 tons and one house per day. During the present 1952-53 season, it is estimated that another 10,000 tons and 60 houses will have been moved in by the middle of February.

Winter tractor freighting is unique in that it is done from rail end or road end into remote and undeveloped country typical of the Canadian Shield in Northern Canada. It must be done in the depth of winter when the lakes and swampy muskegs become ice-covered and passable, and the transportation operator suits his techniques to winter conditions and takes advantage of climate and weather.

First task is careful and thorough road preparation, for the success of this undertaking depends largely on the quality of roadbed. As the ice thickens and snow blanket above it gets deeper with the progress of winter, the freezing process slows, for the snow blanket becomes an effective insulator. It is necessary to get onto the ice as soon as possible with light equipment and keep the snow down. This is done by using a light, fast, track equipped vehicle, the Bombardier snowmobile, designed specifically for winter travel in the north. These machines can take to the ice when it is about 6 in. thick. Running back and forth, packing the snow over the 70-ft wide roadbed permits penetration of the frost and building of the ice. Snow is not ploughed, for this would leave snow banks on either side of the road which would give added insulation and further slow freezing, producing zones of thin ice paralleling the road. Increased cold causes shrinking and cracking of the ice. When ice thickness reaches 18 to 20 in., regular freighting operations begin with smaller tractors and light loads of 4 tons per sleigh.

Freighting unit is the swing, made up of three tractor trains. Each tractor hauls three or four sleighs carrying about 10 tons per sleigh to make up a train. Single loads greater than 10 tons are set on special sleighs. The swing travels to destination and return as a unit at about 4 mph, taking 50 hr to Lynn Lake loaded and 30 hr back to base light. Crew on a swing consists of six drivers, two "brakies" or helpers, and a cook.

The swing is always moving with three drivers and "brakie" on shift. How the shifts are worked is left to the mutual arrangement of the men, but usually they work 'four on and four off' when conditions are severe. One caboose with each swing provides sleeping quarters and kitchen facilities.

Equipment for this operation comprises eight D-6 Caterpillar tractors, eight TD-18 International tractors, six Linn half tracks, two HD-7 Allis-Chalmers tractors and one D-4 Caterpillar. One swing remains on the road constantly for maintenance and repair of road and to assist other swings. Four Bombardiers start the road at the beginning of the season, then patrol and service it.

Gregg-McLaren bob sleighs are used. These have two runners in front and two behind, attached by cross chains so that the rear runners always travel in the track of the front ones. The sleigh, about 20 ft long, is hauled by an attached V-pole tongue.

Houses are transported upon similar sleighs, but sleigh length approximates house length. Bunks on these sleighs extend up to 14 ft, and in the case of large buildings, tricycle arrangement is used with two pairs of runners in the back. Houses have outriggers added to them to prevent tipping.

Weather is the main control of the venture. It is necessary that temperatures go lower than 20° below zero. Too much snow impedes freezing of lakes and muskeg, but too little does not provide sufficient fill and good sliding surface on overland sections.

Under these conditions a plant and a town are being moved. The plant includes mine headframe, hoist house, compressor house, crushing plant, milling and concentrating plant, warehouse and shops. The town included among its buildings a bank, a school, and several churches. While the last members of the warehouse building were being dismantled, the first children left school one day and entered another school the next. Families have vacated their homes and re-occupied them 10 days later, 165 miles farther north.

This has been a major move, not just one of supply. It turned what might have been a scrap heap into a hard-to-replace mining unit. What might have been a ghost town becomes a thriving new community.

LEFT: Lynn Lake townsite at the end of the winter freight trail. Mine shows in background. RIGHT: Closer view of mine area shows concentrator skeleton rising at right, mine plant and crusher house at center, and completed shops and warehouse in foreground.

Financing Domestic Mining Ventures

Part I Problems of Mine Financing

Directed primarily at the methods and problems of financing domestic mining ventures—projects involving one or more of the stages: exploration, development, commercial operation.

by C. C. Bailey, L. C. Raymond, and W. F. Boericke

MUCH of the material involved in a complete coverage of mining venture financing deals with the major projects where the principal interested parties are usually well established mining concerns and government agencies. It is hoped, however, that discussion of all aspects of the subject will provide background and ideas helpful to the larger number who face problems of financing small to medium-sized projects in early stages of exploration and development.

Because of inherent risks of mining projects, stemming from the fact that they involve "wasting assets," their successful financing requires *risk* or *venture* capital. This, in turn, means that generally the most satisfactory procedure for all concerned is to allot to the providers of capital a percentage of the ownership equity.

Problem From Vendor's Standpoint

It is practically axiomatic that the problems and difficulties of securing equity financing and the price in percentage of ownership and in expense of fund raising vary directly as the degree of risk in the project. The greater the risk, the more difficult and costly is the financing. In general terms, the essence of the problem is the appraisal of the risk factor in all its various aspects and from the diverse viewpoints of the vendor and investor of capital. The term "vendor" is used in the sense of the person or persons who own or control the property which is conceived to afford the prospect of profitable commercial operation. The "investor" is the person or group providing the "risk" capital to carry on the project. It must be recognized that the vendor has usually already contributed or "invested" a considerable amount of value in the project in one or more ways. These ways are: 1—securing control of the property, 2—contributing time and effort, knowledge and skill, and 3—expending appreciable cash funds. The amount of such contributions and the degree of accomplishment they represent are important considerations in determining the percentage of total equity that the vendor may reasonably retain when he accepts into partnership a significant amount of outside "venture" capital.

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The question is sometimes asked, "At what point in a new mining project is it desirable to seek outside capital?" The answer is, "When the resources of the vendor available for the purpose have become fully committed, and if at such point the project continues to offer the prospect of successful operation upon application of further capital funds."

Appraising the Risk Factors

When the need and time for financing have been reached, whether the project is essentially in the exploratory, development, or commercial operation stage, it becomes necessary to reduce to reasonably precise terms the evaluation of the risk factors and profit potentialities. For discussion of this evaluation process, the risk factors may be divided into two general categories: internal factors and external factors. The internal factors are those which derive from and concern directly the individual project and its potential place in the mineral-economics pattern of the present and the applicable future. The factual information concerning the property is inescapably the responsibility of the vendor, who must organize and present this material in a comprehensive and competent Engineer's Report. The scope of this report must describe the potential position the project holds in the economic scheme of things; and this phase overlaps into the broad category of external risk factors, which is the area of the investor of "venture" capital.

In the realm of external factors which are beyond the immediate horizon of the vendor (though no less vital to his project) are considerations of the supply and demand of venture capital in general. Here are found the problems of: 1—basic economic trends (conditioned by political climate and trends); 2—monetary and financial conditions, such as volume and availability of credit in general, interest rates, character of equity security markets including price-earnings ratios and stock yields, both current and prospective; and 3—competition from other types of projects seeking "venture" capital, such as are found in the oil industry and in new growth fields in chemicals and new manufacturing processes.

It is obvious that successful financing is most likely to be achieved when the circumstances sur-

Part II, "Sources of Capital Funds" will appear in the July issue of MINING ENGINEERING.

► *What are the limitations and problems of financing?*
► *What time factors influence financing?*
► *What is the cost of financing?*
► *Where to go to finance?*
► *What can be financed?*

rounding both internal and external factors are favorable, and difficulties and costs will be lessened in proportion to the degree of propitiousness of both classes of circumstances. In most cases, the determining motivation and the initiative arise on the part of the vendor, and it will obviously increase his chances for success if he not only thoroughly prepares the information concerning the internal factors, but also appraises thoroughly the external factors which will enter into final determination.

Four necessary elements must all be present for a mining venture to achieve final success:

1—There must be established or in prospect a sufficient tonnage of potentially commercial grade ore favorably situated with respect to power, water supply and transportation.

2—There must be in existence (or susceptible of development) an adequate market for the output of the property.

3—There must be on hand or readily procurable a competent and efficient management, without which there can be little success.

4—Last, but not least, there must be adequate capital to complete necessary development work, construct and install mine and mill equipment, and supply sufficient working capital to allow for reasonable contingencies in a new operation.

The Engineer's Report

As pointed out, it is the vendor's responsibility to supply the necessary information and data to present his project to potential investors. Examples could be cited where worthwhile mining prospects and ventures have been turned down because the necessary data to evaluate the project was not available. Whether the project involves a small amount of capital or whether it has reached the stage where large sums of money are required, the proper presentation of the essential data is of utmost importance. There is no rigid order or ironclad procedure, but there are certain fundamental points to be considered in any effective presentation.

The vendor should not go to prospective sources of financing and expect them to dig up and assemble all the necessary information required for appraisal of the venture. Such work must be done by the principal seeking the financing. The second point is that accuracy and reliability of data describing the venture will be of special importance to any investor. Thus, any supporting information which

Guide For Financing Mines
Major Criteria and Indicated Source

Apparent Characteristic of Venture as Determinable From Data and Policies at Time of Financing	Source of Financing						
	A	B	C	D	E	F	G
Low Risk. Guarantee of Profit after Depreciation, Amortization and Taxes.						√	√
Sufficient Reserves for Scale of Operation and Necessary Life to Pay Off Investment.			√			√	√
Favorable Market Forecast for Product.	√	√					
Good Possibility of Developing Large Reserves.		√	√				
High Financial Responsibility on Part of Vendor.						√	√
Experienced Management and Know-How on Part of Vendor.	√	√			√	√	
Capital Requirements Very Large.	√					√	√
Technical Process Difficult or Process Untried.			√				
Control of Management and/or Majority Ownership Demanded by Vendor.	√	√			√	√	
Long Term Pay-off Terms for Vendor.						√	√
Possibility of Early Money Return to Vendor.	√		√				
Property in Production Stage — Dividend Paying.	√	√				√	√
Time and Effort for Financing at Minimum.		√	√	√	√	√	
Substantial Participation on Part of Vendor.						√	√
Minor Portion of Initial Financing Cost Borne by Vendor.	√			√	√	√	
Stage of Development — Very Early.	√	√	√	√			
High Risk. Low Margin of Profit. Limited Reserves Indicated. Strategic Importance of Minerals Stressed.				√	√		

A—Public Offering
B—Private Individuals and Syndicates
C—Established Mining Concerns
D—Defense Minerals Exploration Agency
E—Defense Minerals Procurement Agency
F—Reconstruction Finance Corporation
G—Institutional Funds

enables the investor to have confidence in the factual data is important.

Scope of the Report

The primary objective of presenting information for financing purposes is to convince the investor that by putting his money to work he will have an opportunity to realize earnings and profits. While one could offer a long list of factors likely to be covered in a feasibility report of a mining venture, data required to analyze the economic factors fall into basic categories:

1—Potentially available ore reserves and possible life of a venture, including details on general geology, basis of determining ore, availability of ore, availability of mill sites, tailings disposal areas, mining losses, and possibility of additional ore development.

2—Potential sales realization from the products recovered from the ore with such details as grade of ore, metallurgical losses, availability of markets, conditions affecting future demand and prices for the products, and their competitive position.

3—Detailed operating costs describing development, mining, haulage, handling, milling and treatment costs, cost of maintenance and supplies, power costs, freight, selling and marketing costs, and general and administrative costs.

4—Capital costs, namely depletion, depreciation, and amortization, would include preproduction costs, the costs of buildings, equipment and facilities necessary for production, as well as inventories and working capital.

5—Federal and state income taxes which would affect the net profits to the investor.

Competent organization and presentation of such an Engineer's Report make possible the formulation of a detailed estimate of the profit potential of the contemplated operation. Such material should be included in the report, and might be briefly summarized in the form shown in the next column.

In cases where the project to be financed is in the initial or very early development stage, little of the above data can be supplied. Therefore, the presentation will be confined to data which tend to support the possibility of the prospect reaching a stage of earning power. In such cases, the amount of money required to reach the next stage is usually not great and the cost of assembling data for making a sound presentation by independent engineers may run from $3,000 to $20,000 depending upon the size of the project.

Estimated Pro-forma Income Statement

	Per Ton	Per Annum*
Sales Realization	$20.00	$700,000
Operating Costs	13.80	483,000
Gross Profit	$ 6.20	$217,000
General & Administrative Costs	.90	31,500
Net Operating Profit	$ 5.30	$185,500
Depreciation	.80	28,000
Net Profit Before Taxes	$ 4.50	$157,000
Provision for Income Taxes**	1.20	42,000
Net Profit After Taxes but Before Depletion	$ 3.30	$115,500

* Based on 100-ton-per-day mill operating 350 days per year, or 35,000 tons of ore per year.
** After adjusting for deduction of percentage depletion.

Many mine ventures in recent years have been very ambitious projects requiring such features as large scale hydroelectric developments, extensive railroad, harbor, dock and ocean transportation facilities, new or complicated treatment and untried processes, in addition to long negotiations with attendant legal problems. In such cases a financial firm or agency will require a critical investigation and all necessary data to demonstrate the feasibility of the entire project. This in turn requires experienced professional help, including mining, mechanical, electrical, civil, chemical and metallurgical engineers, geologists, accountants and lawyers. When such complete engineering and financial investigation is involved (especially if public financing is required) the cost of studies and investigations and of feasibility report may run from $20,000 to $350,000, or more.

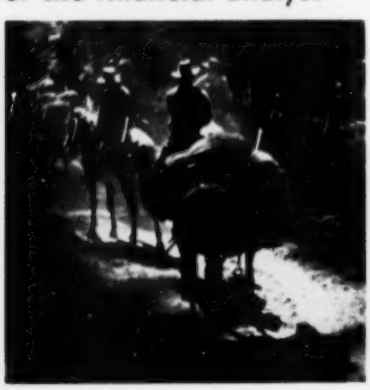
Problem From Investor's Standpoint

The Engineer's Report is the primary instrument upon which the vendor must rely to interest outside "venture" capital in his project. When properly prepared, this report will tell the prospective investor what he needs to know to reach his decision. It will answer practically all his major questions, either directly or indirectly by supplying the pertinent underlying information and data.

In brief summary, the prospective investor will want to know:

1—The history of the property—including details of all prior exploration and development work.

At each stage—prospecting—exploration and examination—development—operacreation of a mine from a prospect. The thousands or millions of dollars that enter of the financial analyst—



2—Present legal status—ownership, etc.

3—Extent of vendor's investment therein and what has been accomplished.

4—Ore reserve position—proven, probable, possible (geology, assays, maps, etc.).

5—Product or products to be extracted—methods and production rate.

6—Current and prospective markets and prices.

7—Details of capital requirements—how much and for what, and time schedule.

8—Detailed estimates of revenues, operating costs, overhead, fixed charges, and taxes.

With this information adequately presented the investor will be able to reach a decision on conditions under which he would be prepared to supply the requisite outside capital; the principal question he would ask being the percentage of equity that he will receive. Since a mine is a "wasting asset," the investor is vitally interested in appraising the time required to return his investment to him out of the net profits, before depletion, and the potential of future profit that will remain in the project at that time.

If the project has reached a point that makes possible a reasonable "estimated pro-forma earnings analysis" similar to the example given, such data must be evaluated in relation to the overall capital investment and the proposed equity position of the investor. The potentialities indicated will be appraised in the light of such general yardsticks as the Hoskold formula, comparison with investment and profit ratios of similar going concerns, and comparison with investment return rates in the security market, and with the return rate on no-risk use of money.

Using the above hypothetical case as an illustration, it appears from the figures that the operation might be expected to yield a net operating profit in the order of 25 pct of sales and a net profit after taxes but before depletion equal to something like 16 pct of sales. An overall investment in the project in the order of $700,000, including a reasonable amount of working capital, would be equivalent to about $20 per ton of annual output and the net profit of $3.30 per ton would represent a per annum return of about 16½ pct on the overall investment. It would take about 6 years at this rate to recoup the total investment. If the investor had contributed one-half of the total investment funds, or $350,000 and had received for it 50 pct of the equity, he would have his money back in 6 years and would still have the prospect of substantial continued annual income for as many more years as the reserve of profitable ore lasted. In the event that the investor contributed as much as 75 pct of the total investment, which would be some $525,000, and received only 50 pct of the equity, it would require nearly 8 years before the net earnings accruing to his portion of the equity would equal his investment.

Importance of Incorporation

In seeking outside capital, the vendor should realize that the corporate form of organization is preferred. Except for some of those cases in which a small project is in its early exploration stages, a corporation will have been already formed before the need for outside financing has arisen. In general, and especially if a public offering is contemplated, the equity should be in the form of non-assessable, rather than assessable, common stock.

In view of the inherent risks in developing a new mining project, it is most logical that the capital structure of the corporate vehicle should consist entirely of equity financing, i.e., without any long term debt obligations. It is in fact generally preferable that only one class of ownership security be issued, namely, common stock. While there are many cases that can be cited in which bonds or notes or preferred stock have comprised part of the capital structure, for the most part these are only justified in projects which are of considerable magnitude and which have advanced considerably beyond the pure prospect or exploration stage.

Probably the great majority of cases, particularly those of relatively small dimensions, reach the stage where outside funds are needed early in their evolution. It would be quite impractical to provide at the outset of a project, which is a prospect, the entire capital funds which would be required to take care of successful exploration, development of property and facilities for production, and the first stages of commercial operation. Thus, sound financing plans contemplate making capital available step by step as the project advances from one stage to another. In cases where public financing is undertaken, it has been common practice in Canada, with respect to projects initiated on a small scale, to arrange the financing so that it would automatically provide a flow of new capital into the company's treasury over

tion—and expansion with changing conditions—finance is a vital element in the a project must come from somewhere—how, at what cost, and when, is the problem

a period of time during which the project is visualized as advancing through various stages to its maturity. This procedure may be illustrated as follows:

Providing a Flow of Funds

The following illustrative material and the hypothetical option schedule are taken from Mining Text Booklet No. 4 of the Vocational Courses for Service Personnel, published in 1945 by the Canadian Legion Educational Services, Ottawa.

An investment brokerage firm sets up the financing program involving formation of a corporation, in case one has not already been formed, or revamping the existing capitalization, to meet the program's requirements. The vendors will receive a percentage of the company's capital stock and sometimes a small cash compensation if an appreciable cash investment in the project can be shown. The vendors' stock interest may run from 15 to 40 pct of the total authorized, the balance remaining available for public sale. Most of the vendors' stock interest is pooled or held in escrow so as to prevent such stock from coming onto the public market in any appreciable amounts during the various financing steps and thus hampering the public sale of stock.

The investment firm will receive options covering the balance of the authorized capital stock over that allocated to the vendors. These options will allow the underwriting firm to purchase stock from the company's treasury at stated intervals and on a gradually ascending scale of prices. If the firm fails to exercise any one of these options at the stipulated price during the specified period, the balance of unexercised options is cancelled and the firm is under no obligation to provide further funds. A hypothetical example of such a program might be detailed as follows:

Authorized common stock, no par value	3,000,000 shares
Allotted to vendors (30 pct)	900,000 shares
Balance for financing (Optioned as below)	2,100,000 shares

Schedule of Options to Investment Firm as of December 1st:

100,000 shares to be purchased by Dec. 31 at 5c	$ 5,000
200,000 shares to be purchased by Jan. 31 at 6c	12,000
200,000 shares to be purchased by April 31 at 10c	20,000
200,000 shares to be purchased by June 30 at 15c	30,000
200,000 shares to be purchased by Aug. 31 at 20c	40,000
200,000 shares to be purchased by Nov. 30 at 25c	50,000
300,000 shares to be purchased by Feb. 28 at 30c	90,000
300,000 shares to be purchased by June 30 at 50c	150,000
200,000 shares to be purchased by Sept. 30 at 75c	150,000
200,000 shares to be purchased by Dec. 31 at 1.00	200,000
2,100,000 shares	Total proceeds to company $747,000

It will be seen that such a schedule determines precisely the funds which the company may hope to receive, but does not stipulate the prices at which these respective blocks of stock may be sold to the public. The investment firm must, of course, comply with all legal requirements, making the proper filings and securing approval of the appropriate Security Commissions.

This method of financing has been used little in the U. S., particularly in recent years, and one basic reason for this is the greater comparative maturity of the mining industry in this country in relation to the remaining unprospected areas which appear to offer potentialities for small scale exploration. Furthermore, development of new mining projects in this country has been subject to difficulties arising from factors beyond the physical attributes and characteristics of potential mining properties. In general, these are factors relating to competition for available venture capital on the part of other types of industries.

Tax Burdens

The high tax burden has been a powerful deterrent because of inherent risks in mining ventures. Exemption from income taxes during the early years of operation (such as is now provided under Canadian law) would be a helpful incentive in many cases. Along the same line, a more liberal depletion allowance would help in securing capital for mining ventures, since the present provision of 15 pct of gross value of output (subject to the limit of 50 pct of net income) is not much more than one-half of the depletion allowance of 27½ pct accorded to the crude oil production division of the petroleum industry. The latest change in Federal tax law affecting the mining industry was enacted in 1951 and provided greater latitude, particularly for the small enterprise, in the treatment of expenditures for mine exploration and development. For taxable years ending after December 31, 1950, the law allows deduction of expenditures for locating and exploring any mine or deposit (other than gas or oil) to the extent that such expenditures do not exceed $75,000 and to the extent also that they are incurred or paid before the development stage is reached. As an alternative, the taxpayer may elect to treat such expenditures as deferred expenses which will then be deducted ratably as the minerals discovered or explored as a result of such expenditures are sold. With respect to properties in the development stage, the taxpayer now has the choice of deducting certain development expenditures either in the year in which they are paid or incurred, or ratably as the produced ores are sold. Under the previous law, during the development stage all expenditures in excess of net receipts were required to be capitalized and then later recovered through depletion. This constituted a helpful step in the right direction but should be supplemented by more favorable treatment with respect to other aspects of taxation if there is to be any significant overall relief from the restrictive effects of present tax laws.

Quite apart from the specific tax provisions applying to mining, there is a serious deterrent to the employment of venture capital in any type of industry in the extremely high rates at which corporation income is taxed and in the steeply graduated scale of tax rates applied to individuals. In general, small scale ventures have to rely to a large extent upon private individuals of comparatively substantial means, having higher than average annual incomes, to supply their venture capital needs. In addition to the stifling effect of high personal income tax rates such owners of potential venture capital are seriously discouraged by our system of double taxation, whereby corporate income first is taxed as such and then taxed again when distributed as dividends to the individual stockholders.

The application of accelerated depreciation to new facilities directly devoted to increasing the production of goods essential for the defense program provides immediate tax benefit to qualifying mining projects. This procedure compresses depreciation of the facilities into a five year period instead of the usual approximation of their actual life span. On the other hand, the potential tax savings of the first five years may be more than offset over the succeeding 10 to 20 years during which depreciation charges will be reduced. Thus it is often difficult for management to reach a satisfactory decision on the acceleration privilege.

Reprints of "Financing Domestic Mining Ventures" will be available after publication of Part II in the July issue of MINING ENGINEERING at a cost of (35¢) per copy. Due to cost of handling, remittances must accompany orders for reprints of this article.

Trackless Equipment Maintenance Accented By TCI

by Hal M. Scrugham

UNITED States Steel Co.'s Tennessee Coal & Iron Div. Wenonah mines present definite materials handling problems arising from the natural features of the operation. Trackless equipment went a long way toward supplying the answers—but at the same time gave birth to several new posers. Machines—trackless or otherwise—require maintenance and Wenonah's experience may do much to add to the body of information already available on this type of equipment.

Let's look at the mines themselves. Ore is of sedimentary origin, extending over an area of several square miles. A thickness from 8 to 14 ft is mined. Bed dip varies from the horizontal to 20 pct in local rolls. Practice is to mine across the dip at 14 pct or less. A parting forms a smooth footwall in some of the mines while in others the footwall must be blasted smooth. Ore weighs 215 lb per cu ft in place and is extremely abrasive.

One of the primary reasons for stressing maintenance at Wenonah is the belief that its solution offers the greatest opportunity for improved operations. Thus, motivation for progress made in trackless equipment maintenance at Wenonah is tied up with optimum utilization of the mine.

Number 11 mine, Ishkooda div., installed trackless equipment in 1947. After that its use spread to all three of the iron mining divisions and to the underground limestone mine. Seventeen trackless loading units operate in TCI mines. Each unit consists of a caterpillar mounted loader, two pneumatic tired shuttle cars, two pneumatic tired drill jumbos, a caterpillar mounted roof bolting machine, and in some cases a portable elevating conveyor and an electric bulldozer.

HAL M. SCRUGHAM is now Superintendent, Gorgas mine, Alabama Power Co.

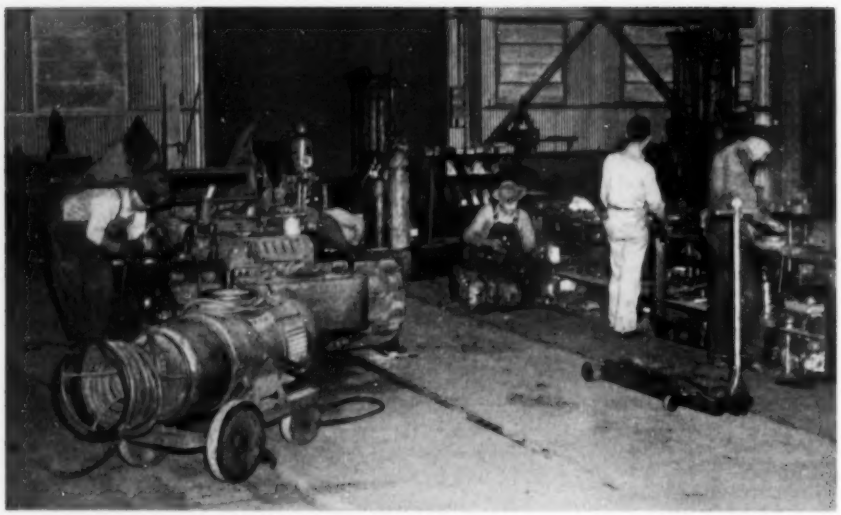
Hard core of the program at Wenonah Div. mines is the preventative maintenance crew. Crewmen are responsible for replacement of unit assemblies. Here one of the crew replaces wearing plates.

Shops in underground sections are equipped with drill press, grinding equipment and a full set of hand tools. Subassembly units are kept in storehouses in individual mines.

From the first, maintenance proved to be a difficult problem. When trackless equipment was introduced at the mines no one could say with surety what the machines were capable of doing. Equipment ran to the point of breakdown and after repair returned for more punishment. Obviously the law of diminishing returns stacked the odds against such a procedure. Breakdown compounded upon breakdown to quickly drive home the importance of maintenance. Once the necessity of a unified program became apparent, all efforts were directed toward making preventative maintenance more than a juxtaposition of two important sounding words.

Manufacturers and their representatives worked closely with TCI engineers and maintenance personnel to improve design of the variety of equipment employed. Thorough study by the industrial engineering department established the life of various machines and their subassemblies. Against this background of manufacturer cooperation and staff research a maintenance program divided into underground and surface components was devised.

Underground maintenance work is performed in mine sections where the machines operate. Shops in



Major repairs are performed in a central shop located aboveground. All major overhauls are made at the central shop and weak points in older machines are strengthened in accordance with latest design.

each section are equipped with a drill press, grinding equipment, and a complete set of hand tools. Subassembly units are kept in central storehouses in individual mines. Items which may be needed for frequent changes are cached in the sections.

The underground program includes lubrication, hard surfacing, minor repairs, change-out of unit assemblies, and when necessary change of main motors of loader units. There is a further subdivision for underground maintenance—maintenance during shift hours and preventative maintenance.

An electrician and mine mechanic compose an operating shift maintenance crew. All units are checked at the start of an operating shift. Machine operators lubricate equipment while maintenance personnel check the equipment for complete lubrication. The hydraulic system is also checked closely.

A preventative maintenance crew is composed of two electrical and four mechanical maintenance men. These men work two full shifts at the end of each 10 operating shifts. One of the primary tasks they are charged with is the changing of unit assemblies, which include clutches, gathering arm brackets and gathering arms, speed reducers, conveyor and drive chains. Unit changes are made on a tonnage basis. Design improvements raised the tonnage life of the various items, and future improvements promise even more.

Machine operators lubricate equipment and maintenance men check general condition of lubrication. The process takes place at the beginning of every shift and has helped prolong working life of trackless equipment.

Another responsibility of the preventative maintenance crew is the hard surfacing of surfaces subject to extreme wear, as conveyor bed plate at the junction of the conveyor boom and the loading head, gathering brackets, gathering head plates, gathering arm discs and the saw toothbill. Conveyor bed plates are not hard surfaced, except as noted, because of excessive conveyor chain wear when passing over hard surfaced areas.

The maintenance crew also replaces gathering arms. Rebuilding and hard surfacing of gathering arms are done in the central shop above ground. Electric motors are carefully checked, with inspection of brushes, brush holders, and bearings. If the motor needs repair above and beyond minor repair, the entire unit is changed.

Electrical crews inspect contacts, power cables, connections and control panels. The crew is responsible for reclamation of power cables when they are no longer needed in original locations. Recoverable cables are sent to the central shop for permanent repairs and vulcanization of insulation.

A log book is kept for each machine. Operating shift personnel and preventative maintenance crews note every repair or subassembly change. Entries must be complete, giving date, time, cause, and delay incurred. Major repairs, with the exception of emergency main motor changes, are made in the central shop. Here, all major overhauls are made. Overhaul time is determined by tonnage loaded by the machine. Weak points in older model machines are strengthened during the overhaul period with more advanced replacements. Three complete changes in loader design during the first five years reflect efforts expended in operation improvements.

While much has been learned in the battle to maintain uninterrupted operations, much yet remains to be learned before TCI's maintenance goal will be reached.

Mining in Mexico

by Howard S. Strouth

Building roads by hand labor and dynamite, due to unavailability of road building equipment, is slow, but not expensive.

SINCE the days of the Conquistadores, people have told exaggerated tales of the wealth and possibilities of Mexico and Central and South America, and the mining fraternity has never been known to exaggerate any less than any other professional group known to man or beast.

However, during a short stay in Mexico one can probably hear more whoppers than at any other time, when dozens of mining propositions are thrust across the desk, and it is not necessary to remind anyone that a listing of the do's and don't's for Mexico requires special mention of the fact that most mining propositions offered south of the border eventually turn out to be a beautiful fairy tale.

The following is not suposed to be either an exact description of Standard Mining Corp.'s operations in Mexico by its mining associate, the Corporacion Minera y Beneficiadora Anahuac, S.A., or the last word as to the most economical way to start such an operation. But rather it is the sum total of the recent experiences of the writer while commencing such an operation in 1951-52 with the help of many qualified gentlemen.

Choice of Mines

In choosing a suitable mining operation it was found advisable to concentrate on a group of lead-zinc-silver mines within an area of 100 sq kilometers. By a process of elimination six mines were eventually acquired and put into production in the state of Jalisco. The group of six showed great similarity in the type of ore and enough of a production potential to eventually warrant the building of a mill. At the same time some ten additional properties were eliminated, which after inspection or temporary operation proved unsatisfactory. The group of six mines finally chosen showed the following advantages, apart from the similarity of the ores: (a) A small production could be achieved within a very short time while development work was still going on; (b) The tenor of the ore was better than 12 pct Pb as an average, with small gold and silver values and 8 to 10 pct zinc; (c) Most of these properties having been worked previously, it was possible without too much drilling to ascertain a substantial blocked out reserve.

Needless to say, while doing this work the company was swamped with offers of selenium mines, where somebody had kindly substituted the symbol Se for the symbol Si and by this simple process turned plain silica into selenium; tungsten properties which belonged to half a dozen people except the man who offered them; fluorspar properties with plans to build a processing plant which, after inspection, indicated roughly 500 tons of ore reserve; and copper mines with veins claimed to be several meters wide, purportedly showing 40 pct native copper, which turned out to consist of small malachite stringers a few centimeters wide. (Why is it always 40 pct Cu?). Like everyone else, we paid for our gullibility by wasting time and effort.

HOWARD S. STROUTH is Vice President, Standard Mining Co.

Size of Operations

It was found advisable, both because of the risk motive, and the lower investment, to set a very modest goal for the first operation, being content with a production of 50 tons a day as a minimum and a relatively small labor force. This restricted the investment to the low six figures, did not attract too much publicity and thereby too many local free-loaders, and did not upset the local labor market. We have since found that this reasoning was wise.

In spite of the fact that some equipment can be bought more cheaply in Mexico, it was decided to import American equipment to which we were accustomed, and also to use United States personnel for the basic setting up of the operations and the drilling program.

At the same time, large scale tests were made by an American firm to work out a flow sheet for a small mill, and preparations were made to purchase such a mill from an American manufacturer with the exception of certain standard pieces of equipment and simple devices, such as jigs, which could be made more cheaply in Mexico. During this phase of the operations a simple jig concentrate of the ores was made, upgrading the lead to roughly 30 pct. This was shipped to local smelters and mills.

Personnel and Labor

A great deal of money was spent in the beginning by using American engineers and personnel exclusively, to initiate operations, but gradually such control was passed on to trained engineers and administrators of Mexican nationality, who proved most satisfactory in the long run under a certain amount of supervision.

We found it advisable to take on foremen at 1200 pesos a month, rather than 400, and to pay an incentive bonus; while on the other hand an increase in pay to the average miner, who gets between 5 and 7 pesos per day, increased neither his efficiency,

productive capacity, nor insured his regular attendance, so that as a long range program provisions were made to settle our labor force permanently in the mine region, providing them with cheap housing, some educational facilities, some free farming acreage, etc., as the only means to attract them permanently and improve their performance. This can be accomplished relatively cheaply in Mexico, even though practically everything, including water, has to be provided by the company.

It was necessary to build 17 to 18 kilometers of road to connect some of our properties and to construct an all-weather road leading to one of the highways. This was accomplished entirely with hand labor and dynamite at a reasonable cost not exceeding $10,000 plus a few hundred dollars a year to keep the road in good repair. This type of work is necessary almost everywhere that mining properties are being opened up in Mexico, and while the expenditure is not too great the amount of manpower and time used is tremendous. However, the availability of bulldozers and other road building equipment is virtually nil.

Transportation Problem

Transportation, the availability of railroad cars and trucks, is one of the most difficult problems in Mexico and is accompanied by a continual greasing of palms, generally referred to as *mordida*. However, on marginal ores this bite can be very painful. Unfortunately, I have no suggestions on how to improve this particular situation.

A further difficulty arises as the result of seasonal changes, harvest periods, etc., during which time the government "confiscates" some of the cars to transport food—and most of your laborers take off to harvest their crops and have a fiesta as long as the fun will last.

Again, during the rainy season the difficulties of bringing the ore to the nearest railroad station or for the laborers to get to the mine often result in interruptions to the work schedule.

It is advisable to keep a substantial and representative office in Mexico City, first of all because it is probably the only place in Mexico one can telephone from the U. S. without waiting a couple of days to get through. Secondly, because a great number of your administrative, tax and legal problems can be solved right there; and last but not least, such an office can be used as a nucleus for doing some ore trading, thereby giving you an additional source of revenue.

Moreover, this location gives one the advantage of personal consultation with consular officials and officials of the local bureau of mines, who have in this case proven exceedingly helpful.

Laws and Taxes

The first thing anyone tells you to do in Mexico is to get a good lawyer to help you fight through the maze of tax laws, mining laws, laws governing the employment of foreigners, export laws, import laws, and some laws that seem to have been especially invented to annoy your particular enterprise. After a while you find out that too much legal advice is more of a handicap than an advantage and that there are a few short cuts. How to proceed from there is between you and your conscience.

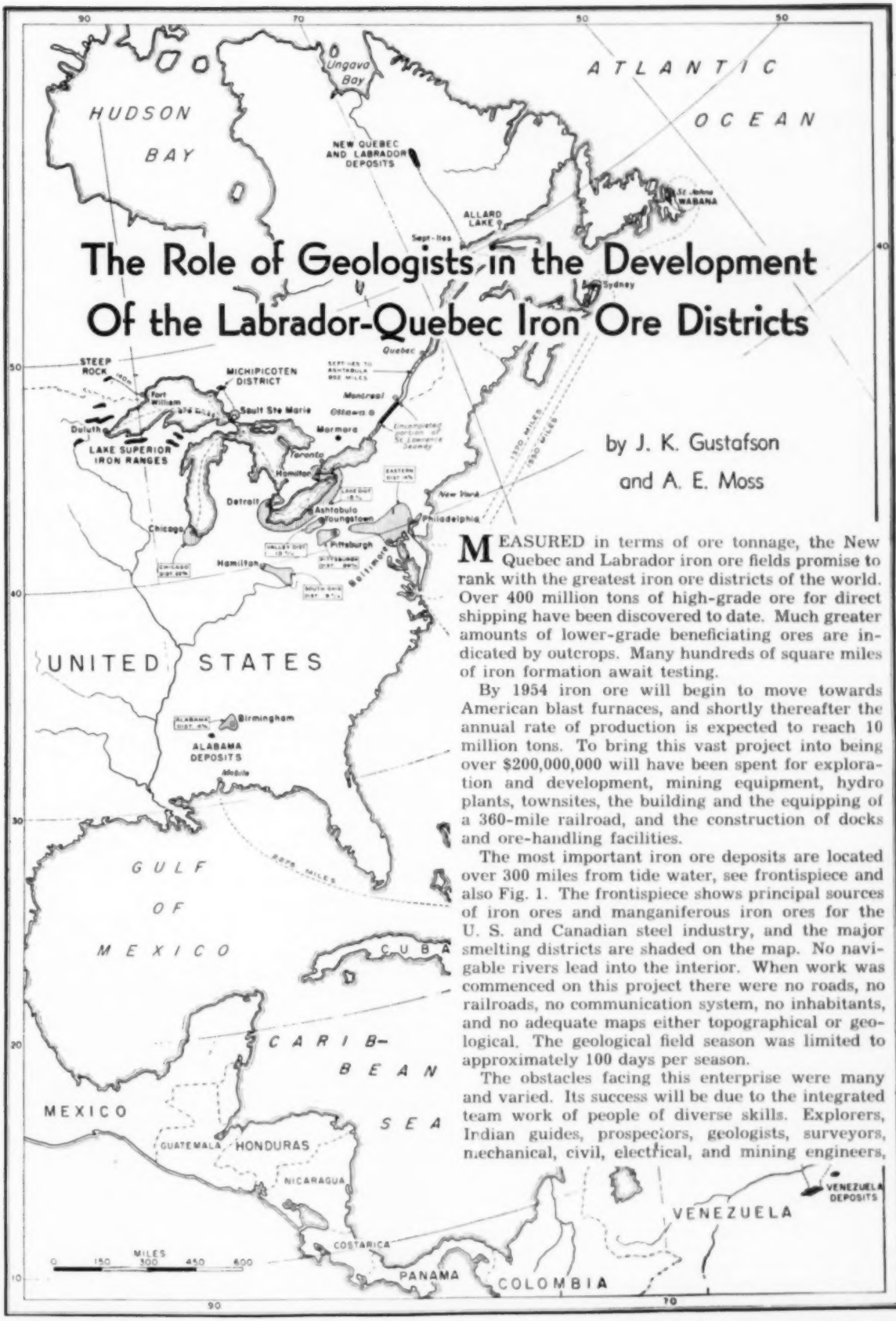
Taxes are not too high on income, but since both a production and export tax will probably have to be paid on the product they will amount to 30 pct or more of the value of your product alone. While it is true that there are small miners' subsidies and certain repayments on production taxes, these usually cannot be counted on as a cost reduction factor by most American enterprises because of the nature of their operations.

Dropping prices of base metals have changed the economic possibilities somewhat but have also increased the opportunities for enterprising American concerns to acquire promising mining properties relatively cheaply and to build up with patience and some luck new metal producers which some day might out-produce similar mines in the United States. Although the dangers and the difficulties should not be underestimated, the opportunities today are doubtlessly greater than ever.

Miscellaneous

Particularly, if you are going to spend any length of time in Mexico City your wife will insist on coming along, which has considerable advantages for you that need not be enumerated. On the other hand, here are some of the drawbacks: In spite of being very careful about food, it is going to make her sick occasionally, the altitude will affect her, and her bargain hunting is going to keep you broke.

LEFT: Headframe at the mine at Matachines, one of the group of properties in Jalisco. RIGHT: Two of the compressors at Veta Grande. Headframe and bin in background serve incline bringing ore up steep slope from mine located on canyon wall below.



The Role of Geologists in the Development Of the Labrador-Quebec Iron Ore Districts

by J. K. Gustafson
and A. E. Moss

MEASURED in terms of ore tonnage, the New Quebec and Labrador iron ore fields promise to rank with the greatest iron ore districts of the world. Over 400 million tons of high-grade ore for direct shipping have been discovered to date. Much greater amounts of lower-grade beneficiating ores are indicated by outcrops. Many hundreds of square miles of iron formation await testing.

By 1954 iron ore will begin to move towards American blast furnaces, and shortly thereafter the annual rate of production is expected to reach 10 million tons. To bring this vast project into being over $200,000,000 will have been spent for exploration and development, mining equipment, hydro plants, townsites, the building and the equipping of a 360-mile railroad, and the construction of docks and ore-handling facilities.

The most important iron ore deposits are located over 300 miles from tide water, see frontispiece and also Fig. 1. The frontispiece shows principal sources of iron ores and manganiferous iron ores for the U. S. and Canadian steel industry, and the major smelting districts are shaded on the map. No navigable rivers lead into the interior. When work was commenced on this project there were no roads, no railroads, no communication system, no inhabitants, and no adequate maps either topographical or geological. The geological field season was limited to approximately 100 days per season.

The obstacles facing this enterprise were many and varied. Its success will be due to the integrated team work of people of diverse skills. Explorers, Indian guides, prospectors, geologists, surveyors, mechanical, civil, electrical, and mining engineers,

The Transactions papers appearing in Mining Engineering during 1953 will subsequently appear in AIME Transactions Vol. 196, and may be permanently referenced to that volume.

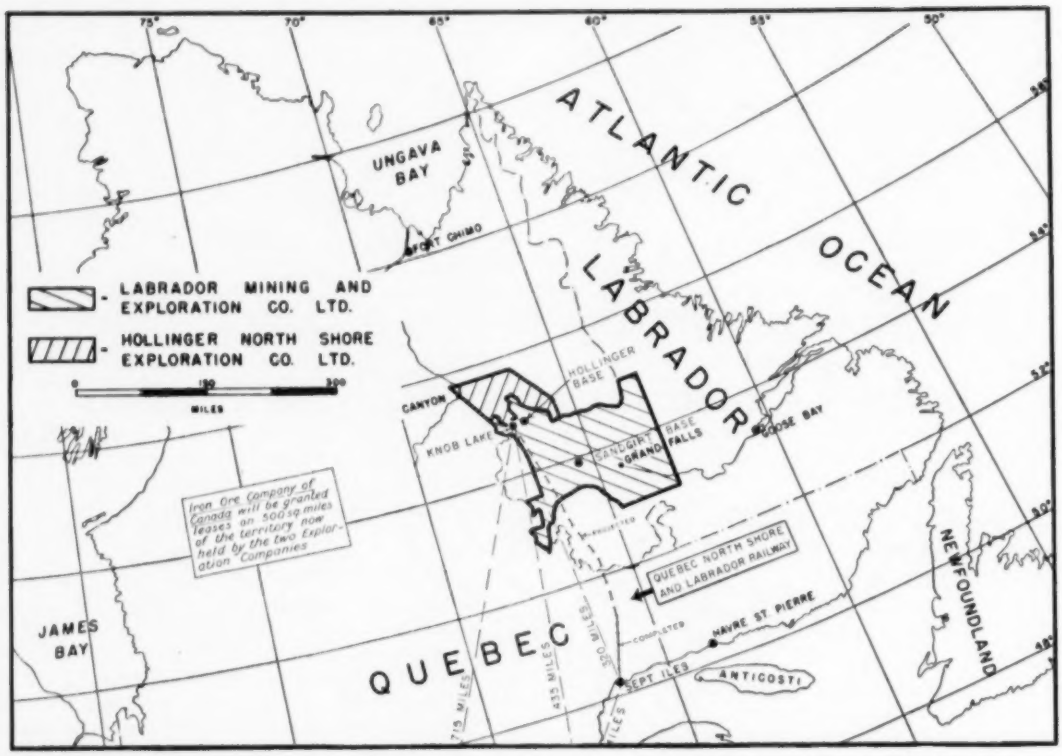


Fig. 1—Principal sources of iron ores and manganiferous iron ores for the United States and Canadian Steel industry.

railway experts, construction experts, drillers, mechanics, aeroplane pilots, cooks, executives, and financiers have all participated.

Hollinger Consolidated Gold Mines Ltd. is a major shareholder and Hanna Coal and Ore Corp. a minority shareholder in two companies, Labrador Mining and Exploration Co. Ltd. and Hollinger North Shore Exploration Co. Ltd., which have exclusive prospecting rights in two large concessions totaling nearly 25,000 square miles in Labrador and Quebec. Ultimately, these concession companies will lease much smaller areas from the Provincial Governments and will each sub-lease still smaller areas to Iron Ore Co. of Canada, a company formed by the same interests in association with five American steel companies for the purpose of bringing this project into production. The American companies are National Steel Corp., Armco Steel Corp., Republic Steel Corp., Wheeling Steel Corp., and Youngstown Sheet and Tube Co.

Within the next few years nearly 95 pct of the concession areas will be returned to the Provincial Governments. Geological work has had two main purposes: 1—to find and develop enough ore to justify bringing this project into production, and 2—to learn enough about the concessions to permit selection in the time available of the best 500 square miles from an iron ore standpoint for sub-leasing. The total areas being investigated are approximately the size of a strip of land 10 miles wide joining New York and Los Angeles.

The object of this paper is to describe this geological effort. That much correlated geological knowledge exists will have to be taken on faith until it is published elsewhere. The staff of the Iron Ore Co. of Canada are now engaged in compiling a detailed report summarizing the geological data gathered by the vast number of geologists who have been associated with this project since 1936. Probably this report will be published in a few months. Sufficient description of geology and topography will be given here to make the paper understandable.

The area under discussion is a glaciated plateau of moderate relief, see Fig. 2. Most of the area is between 1500 and 2500 ft above sea level. Lakes and rivers are numerous, and water covers over 50 pct of the surface throughout large areas. Much of the south-central section is covered by marshes and swamps. The distribution of the vegetation is erratic. In valleys and sheltered areas there are fair stands of black and white spruce with some birch, balsam, and tamarack. Higher areas are above the timber line and are carpeted by white caribou moss. Patches of shrubs grow along slopes and in ravines.

Rock outcrops throughout the northern half of the area are numerous and widespread, although vast continuous rock exposures such as are found in the Northwest Territories are absent. Outcrops throughout the southern portion are chiefly confined to the crests or slopes of the larger ridges. Here, geological features could not be determined by mapping alone. Test pitting, drilling, and/or geophysical methods were also employed.

Although the center of the Labrador ice cap was near this area, evidence of severe glacial erosion is

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Discussion on this paper, TP 35531, may be sent (2 copies) to AIME before Aug. 31, 1953. Manuscript, Feb. 3, 1953. Los Angeles Meeting, February 1953.

lacking. The area is now covered with an irregular, generally shallow mantle of glacial till. In the southern portion thick deposits of gravel and sand are present. Eskers are numerous.

The consolidated rocks are pre-Cambrian. They have been intensely folded and faulted. Many folds are overturned, and abrupt changes in direction and degree of plunge are common. The regional strike is generally northwest-southeast or north-south, but east-west folds and even northeast-southwest structures occur in the southern portion of the area. Strike faults, mostly thrusts, are numerous. Most faults are steep. Small cross-faults occur.

The main ore zone, in which most of the known ore exists, trends northwest-southeast. It is approximately 80 miles long and averages about 6 miles wide. Table I lists the formations of rocks of the main ore zone and vicinity. Fig. 3 shows the surface geology and two vertical cross-sections of a typical area within the main ore zone.

The host rocks of the iron ores are the Sokoman iron formation and the Ruth slate, although in several places the iron ores extend a short distance into the underlying Wishart quartzite. All of the iron formation probably belongs to one stratigraphic horizon, although it is repeated numerous times by folding and faulting. Locally it is intercalated with lava flows and fragmentals of intermediate or basic composition. Unenriched Sokoman iron formation averages about 30 pct iron. It contains iron oxides, iron silicates, iron carbonates, and cherts (locally recrystallized to quartz). Eight to ten rock types within the Sokoman are recognized for mapping purposes. Most rock and ore types can be duplicated in iron ranges of the Lake Superior region.

The ore varies greatly from one orebody to another and even from place to place within individual deposits. Most of the ore consists of mixed hematite and geothite. Deposits of almost pure hematite are known, and either geothite or *limonite* may occur alone. Martite is usually abundant. Occasionally magnetite is present. To date, siderite has not been observed within an orebody although it is prevalent in lean iron formation in some places. The ore ranges from hard and dense to soft and porous. The moisture content varies widely. Approximately 10 pct of the ore is manganiferous and occurs as lenses within the iron ore.

The iron ore of the main ore zone is essentially shallow and is believed to have resulted from the weathering of low-grade iron formation. The structural control of ore deposition is not everywhere clear, although certain structures including synclines were favored during ore formation.

In the southern portion of the Labrador concession a higher grade of metamorphism prevails. Large masses of iron formation averaging over 40 pct iron have been recrystallized to a granular magnetite-

Table I. General Table of Formations for Iron Ore Areas

CENOZOIC			Glacial, lake, and stream deposits	
		Unconformity		
PROTEROZOIC	**MONTAGNAIS** (Keewanawan?)		* Diabase, diorite, gabbro, dikes, and sills	
			Sims Group: Pink and white quartzite	
		Unconformity		
	KANIAPISKAU (Huronian?)	**Point Series**	**Menihek Formation**	Black and grey shales; dolomites
		Unconformity		
		Ferriman Series**	**Sokoman Formation**	Iron formations; ferruginous cherts and slaty members
			Ruth Formation	Rusty, black ferruginous slates
			Wishart Formation	Quartzites
		Unconformity?		
		Hamilton Series**	**Fleming Formation** (restricted occurrence)	Chert breccia
			Denault Formation	Dolomites
			Attikamagen Formation	Grey and green shales
			Seward Formation	Quartzites and grits
		Unconformity		
ARCHEAN	**Ashuanipi Complex:**		Orthogneisses-paragneisses Acidic and basic intrusives	

* In the southwestern corner of the Labrador concession the Kaniapiskan rocks are cut by granites and other acidic intrusives.
** In the eastern portion of the area, these formations are intercalated with lavas, sills, related pyroclastics, and greywackes.

Fig. 2—A photograph showing the terrain of the Labrador-Quebec iron ore district. An airstrip lies near the railroad right of way, which can be seen following the river valley.

specularite-quartz rock which readily makes a high-grade concentrate by gravity separation. Whether this iron formation is richer because of initial differences in sedimentation or because of enrichment prior to recrystallization is not yet known.

History of Geological Work

Geological Investigations Prior to 1936: Prior to 1936 little geology was known. Until the 1890's the few white men penetrating the interior were missionaries and fur traders employed by Hudson's Bay Co. The first geological investigations were conducted by A. P. Low of the Geological Survey of Canada[1] in 1892 to 1895. Low did a monumental job of reconnaissance mapping along several traverses through the interior and along the coast of the Ungava Peninsula. He traced for several hundred miles the great belt of Huronian-type sediments since termed the Labrador Trough. He discovered the iron formation and suggested that the area was favorable prospecting ground for iron ore because its geology was similar to that of the Lake Superior region. During 1892 to 1895 Low travelled approximately 4500 miles by canoe, 1000 miles by boat, 500 miles by dog sled, and 1000 miles by foot, a total of 7100 miles.

In 1929 W. F. James and J. E. Gill[2] conducted an expedition for the New Quebec Co. which discovered the first iron ore in the region. The five geologic teams of this expedition mapped ore showings and made the first rough topographic maps compiled from sketches made during aeroplane flights. In 1933 J. E. Gill led an expedition into the Wabush Lake area which is now part of the Labrador concession.[3] This party, including two other geologists, was organized to examine auriferous quartz veins which had been reported.

The only geological information available in 1936 came from these two private expeditions and one reconnaissance traverse made by Low's party. With the exception of a few sketches, there were no topographic maps. Although the Quebec government had made a stadia traverse along the Ashuanipi River, this information had not been released. No aerial photographs existed.

Geological Investigations from 1936 to 1944: In 1936 Labrador Mining and Exploration Co. was formed, and a concession of over 20,000 square miles was obtained from the Newfoundland government. J. A. Retty was appointed chief geologist. Field operations were based at Sandgirt Lake during the following four seasons. A major problem was the lack of base maps. Sketch maps made from aeroplanes were used to plan the work and to distribute and relocate field parties. Rapid stadia traverses along the main water courses were made during the next three years supplemented with range-finder and compass traverses. From 1936 to 1939, 12 two-man geological parties mapped a considerable area using reconnaissance methods. The stratigraphy and petrology of the region were beginning to unravel by the end of 1939. Iron ore was found in Quebec along the strike of the 1929 discoveries. In 1937 the Sawyer Lake orebody was shown to Retty by an Indian. This deposit was trenched and mapped. By the end of 1939 six of the currently recognized orebodies were found. Work was suspended during 1940 and 1941 because of a shortage of money.

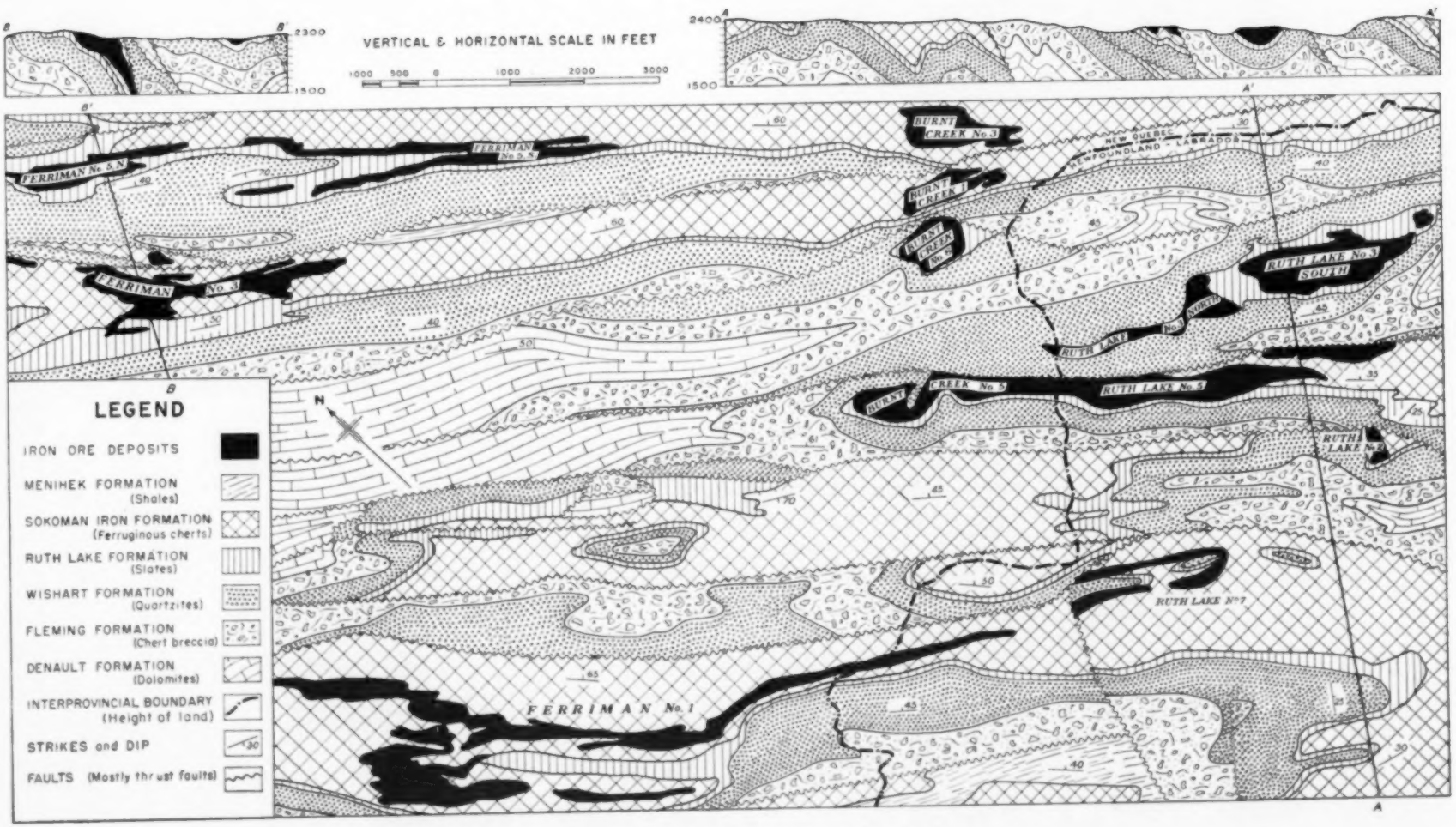

Fig. 3—Geology and iron ore deposits of a portion of the main ore zone.

Fig. 4—A churn drill operating on one of the Fleming ore deposits. Note barren nature of territory.

In 1941 Hollinger Consolidated Gold Mines Ltd., following the recommendation of J. K. Gustafson, obtained an option to purchase control of the Labrador Mining and Exploration Co. Ltd. Hollinger also acquired exclusive prospecting rights on an adjacent area of 3900 square miles in New Quebec on the recommendation of Retty. A new company, Hollinger North Shore Exploration Co. Ltd., was formed to hold this concession. The first Hollinger-controlled geological and prospecting expedition in 1942 was headed by Gustafson with Retty second in command. A. E. Moss was also a member of this party. Aerial photographs being unobtainable during the war, maps sketched from aeroplanes and range-finder and compass surveys were again used, one for planning work and the other for preparing base maps. The principle now in use of mapping observed outcrops along plotted traverse lines was established. Professional prospectors were put into the area. A regional geological map showing a structural and sratigraphic interpretation based on data available at that time was prepared. Iron ore showings were re-examined, but the work during 1942 was concentrated on the search for metals other than iron. More than a hundred large *gossans* resulting from oxidation of sulphides were superficially examined, but no commercial orebodies discovered.

In 1942 to 1943, the M. A. Hanna Co. purchased an interest in both exploration companies. Thereafter the Hanna technical staff, including A. E. Walker and Mack C. Lake to 1949, acted in a consulting capacity. During 1943 and 1944 prospecting, detailed and reconnaissance geological mapping, and some drilling were continued under the field direction of J. A. Retty. Several diamond drill holes were drilled into some of the sulphide deposits, and a few holes were drilled into the Sawyer iron ore deposit. Twelve deposits containing 160,000,000 tons of iron ore were discovered by prospectors during this period. The first government aerial maps of the area became available. In 1943 the base of field operations was moved from Sandgrit to Hollinger Lake.

Geological Investigations, 1945 to 1950: Prior to 1945 the exploration consisted principally of semi-reconnaissance geologic mapping and prospecting for nonferrous base metals. In 1945 exploration for iron ore began in earnest in response to the growing realization of postwar needs for new reserves. Detailed mapping and test pitting of known iron ore showings were begun. The surface area of ore was increased many times during 1945 and 1946. This increase resulted mostly from extending the surface area of previously discovered orebodies, although several new deposits were found. In 1946 iron ore deposits in the main ore zone were drilled with diamond drill rigs. Small tractors were flown into the area the same year. The first vertical aerial photographs of the area were taken in 1946 by R.C.A.F.

During the winter 1946 to 1947 an objective was set of proving 300 million tons of direct shipping, open-pit ore as a prerequisite for financing to the production stage. Intensive drilling operations to determine the depths of the large surface area of ore began. The field base was moved from Hollinger Lake to its present site near Knob Lake. Quonset buildings were flown into Knob Lake to house exploration personnel. A portable sawmill was delivered so that buildings could be erected from local timber. A semi-permanent camp was constructed including bunkhouses, dining hall and kitchen, office, warehouses, chemical laboratory, and a modern machine shop. Although most of the supplies and equipment in 1947 were landed on the winter ice of Knob Lake, a land strip was put in operation by early fall so that large aircraft could land the year round. Heavier tractors were flown in and began the first roads. Trucks, jeeps, compressors, and drills followed. Portable churn drills and equipment for converting the unsatisfactory coring drills to chopping drills were purchased, see Fig. 4. The first large caterpillar-mounted churn drill arrived in the early fall of 1947. Three more followed in 1948. Development of air strips and railroad lines proceeded simultaneously, see Figs. 5 and 6.

The 300 million ton objective was reached in October 1948, but by then the requirements had been raised to 400 million tons. By the end of 1950 ore reserves reached the present figure of 418 million tons of direct shipping ore. Over 2700 tons of ore were indicated with each foot of drilling. This high rate of yield was largely due to the concentration of effort resulting from having accurate, detailed geological maps. Thus waste of footage in barren sections was kept at a minimum.

Drill cuttings were used almost exclusively for analyses and ore calculations as it was found impractical to core the ore. Separate samples were collected for each 5-ft section. One to two pounds of each sample were stored for future reference after the sample had been logged and analysed. A binocular microscope proved to be indispensable for determining the mineral and textural composition of the ores and other formations. With it the iron content can usually be estimated within 2 pct.

Most but not all effort during the 1947 to 1950 period was devoted to drilling. In 1947 adits were driven into two of the ore deposits, and three shafts were excavated the following year. These underground workings were driven to check the ore grade as determined from drilling and to obtain information as to structure, specific gravity, and moisture content of the ore.

Much pitting and trenching through the overburden were done. Previous to 1949 this work had been done with hand tools or tractor blades. Small mechanical shovels equipped with a back-hoe attachment were obtained that year capable of digging to a depth of 15 ft. These proved to be tremendously important tools for outlining orebodies.

The specific gravity of the ore received attention during this period. Because large tonnages and great variations in the character of the ore were involved, the problem was complex. Volume factors were determined from the underground workings by weighing all the material excavated and by measuring the volume of the excavation by taking offsets from a template. Although accurate, the results were valid only where there were expensive adits or shafts. After many tests the following procedure was adopted. The overburden was removed to expose the ore over an area of several square yards. The surface of the ore was then levelled and a 2 to 3-cu ft excavation made in it. All the material removed was carefully weighed and the volume of the excavation determined by sealing the walls and bottom of the pit with a rubber-like plastic applied with a spray gun and filling the pit with a measured quantity of motor oil. This method is believed to be superior to those using shot or grain as all irregularities are filled with oil and there is no compaction. The method is inexpensive and quick.

Ground magnetometer and gravimetric surveys of selected areas were made in 1947, 1948, and 1950. The Canadian government and the company established triangulation stations throughout much of the area. Accurate planimetric base maps were prepared from aerial photographs using the triangulation stations for ground control. The company established its own photogrametric section and has prepared base maps of all potential iron ore areas using vertical aerial photographs taken from company aircraft on a scale of 1 in. to 1000 ft.

In 1950 the amenability of marginal ores to beneficiation was investigated. It was found that large tonnages of wash ores are available. Many screen tests were made.

In 1947 and 1948, and to a lesser extent in 1949, large areas along the main ore zone were mapped on a scale of 1 in. to 200 ft using plane tables. In 1949 the program of mapping all areas underlain by iron formation on 1000 ft to the inch was commenced. Outcrops and traverses were plotted on the vertical aerial photographs, and additional notes were recorded on transparent plastic overlays. Each area was systematically traversed, and all outcrops of iron formation were located and classified. In 1949 and 1950 mapping on a scale of 1 in. to half-a-mile and some reconnaissance mapping were resumed after having been discontinued in 1946 and 1947.

Geologists directed a large part of the ore development program of 1945 to 1950. They spotted all drill holes, adits, and shaft sites. They logged all drill holes. Geologists supervised all sampling of drill holes and underground and surface workings. Volume factor and structure tests were under their jurisdiction. They calculated ore tonnages and grades and drew sections and plans prerequisite to these calculations. This work was supervised by A. E. Moss, who was assisted by R. Geren and R. Kirkland, who have recently joined the operating department.

In 1949 five American steel companies together with the Hollinger and Hanna interests formed Iron Ore Co. of Canada, which arranged to sublease areas from the two concession companies. Financing and a full-scale construction program were assured in 1950. Thus a new phase of this project began, although the work continued under the same management. In the same year J. M. Harrison of the Geological Survey of Canada started geological investigations in the area.

Geological Investigations, 1951 to 1952: Once the decision to proceed with railroad construction and iron ore production was made the finding of ore was no longer urgent. Emphasis was now on construction and procurement of equipment and supplies.

A mining department was organized, and several of the geological personnel were transferred to it. Drilling continued primarily to determine pit outlines and to locate screening plants, dump areas, and spur lines off of ore. Additional shafts and trenches were excavated, and many more samples were collected for wash and screen tests. Five-foot aerial contour maps covering over 30,000 acres were prepared to aid in laying out spur lines and mining facilities. The first ore deposits to be mined were mapped on a scale of 1 in. to 100 ft.

The geologists' main problem became one of evaluating large areas underlain by iron formation in order to select the best 500 square miles of territory

Fig. 5—Airstrip at Mile 36 along Q.N.S. & L. railway, one of 13 built for railroad construction. A DC-3 is being unloaded. The rugged country is typical of the first 100 miles north of Seven Islands. Fig. 6—A railroad rock cut along right of way.

for subleasing by Iron Ore Co. of Canada. Triangulation surveys were continued, and thousands more aerial photographs were taken. The 1000-scale mapping program was accelerated, and by the end of 1952 all areas of maximum interest had been mapped on this scale. A few new ore deposits were found but not drilled. An aeromagnetic survey was made of areas of sparse outcrops and of a strip along the railroad route. Approximately 20,000 line miles were flown during this survey. Drilling in 1952 tested magnetic anomalies in drift-covered areas.

The Geological Survey of Canada has published preliminary maps of certain areas investigated since 1949.[4–6] The company has worked in close conjunction with the Survey and has made available to it all company geological data. Harrison published a report on a portion of the district in 1952.[7]

In addition to the aeromagnetic surveys along the railroad route, other geological investigations were conducted outside of the concession areas. Reconnaissance and detailed mapping were done of selected areas adjacent to the railroad route. Iron-bearing beach sands were examined at certain points along the St. Lawrence River.

Future Geological Investigations: The broad geological features of a large territory have been roughed out, and detailed data have been assembled in the vicinity of known ore deposits. Much, however, remains to be done. Geological investigations will continue and iron ore discoveries will continue to be made for many decades. In addition to iron, other metals will require investigation both within and outside the concession areas. Recent detailed drilling has already yielded surprises requiring modification of geological structural interpretations.

Iron Ore Co. geologists will continue 1000-scale mapping and will map selected areas on larger scales. Trenching, pitting, and drilling will follow or accompany detailed mapping. Areas containing beneficiating ores will be re-studied. This spring several geologists will have a conducted tour through pits, plants, and laboratories on the Mesabi and Cuyuna ranges to learn more about wash, heavy media, and other beneficiating ores.

Organization of Geological Work

The year-round staff of the Iron Ore Co.'s geological department consists of a chief geologist, A. E. Moss, who succeeded J. A. Retty in January, 1952; 2 supervising geologists, C. Dufresne and H. E. Neal; 6 other geologists; 4 surveyor-topographers; 4 draftsmen; and a clerical staff of 3. During the field season the staff is greatly expanded. In 1952, for example, the following were on the exploration payroll: 68 geologists and geological student assistants, 4 surveyors, 4 prospectors, 3 drill foremen, 16 drillers, 10 tractor operators and helpers, 2 mechanics, 13 canoemen, 15 cooks and cookery help, 1 medical officer, 1 radio technician, 2 storekeepers, 4 draftsmen, 3 miscellaneous clerical help, 2 carpenters, 10 laborers, and several other employees who spent part of their time on other projects. Field parties consisted of two 2-man prospecting teams, seven 7-man and three 5-man geological mapping parties, 3 triangulation survey parties, 2 mobile drilling camps, and 6 geologists attached to drill camps. All parties live under canvas and move by canoe, float aircraft, or tractor trains. The company operates 6 small aircraft for servicing and supervising field activities. Aircraft visit parties at least once a week with provisions, including fresh meats and vegetables, mail, and other requirements.

Four supervising geologists circulate among the parties to examine matters of economic interest and to direct the work. The chief geologist makes periodic visits to areas of maximum interest, and the consulting geologist makes two or three visits to the field each season. Field parties are supplied with

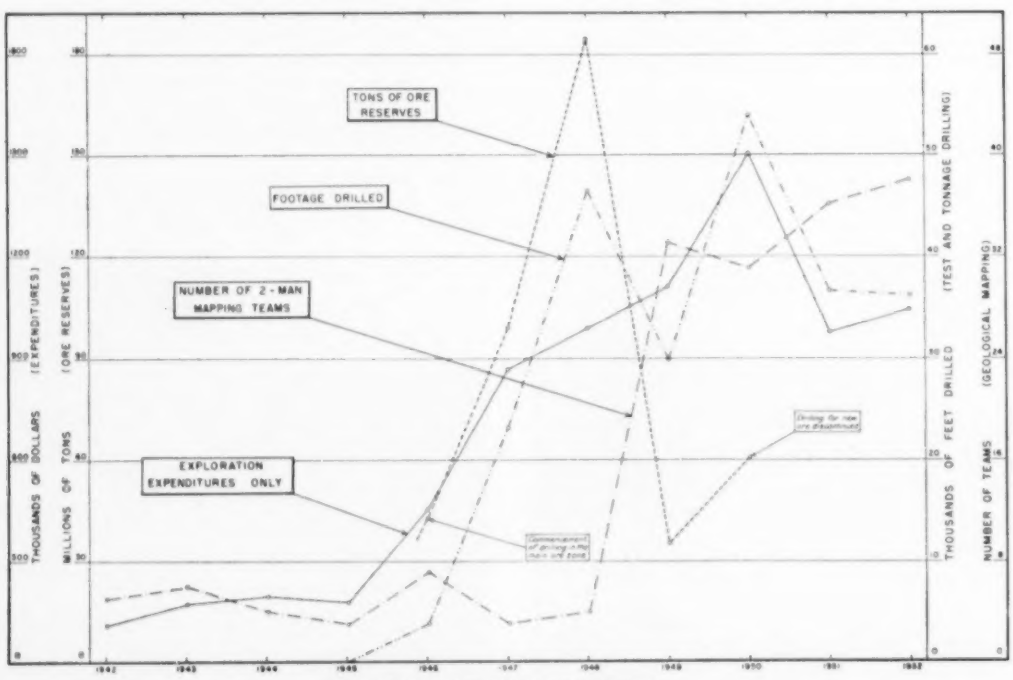

Fig. 7a—Mapping and other exploration effort in recent years.

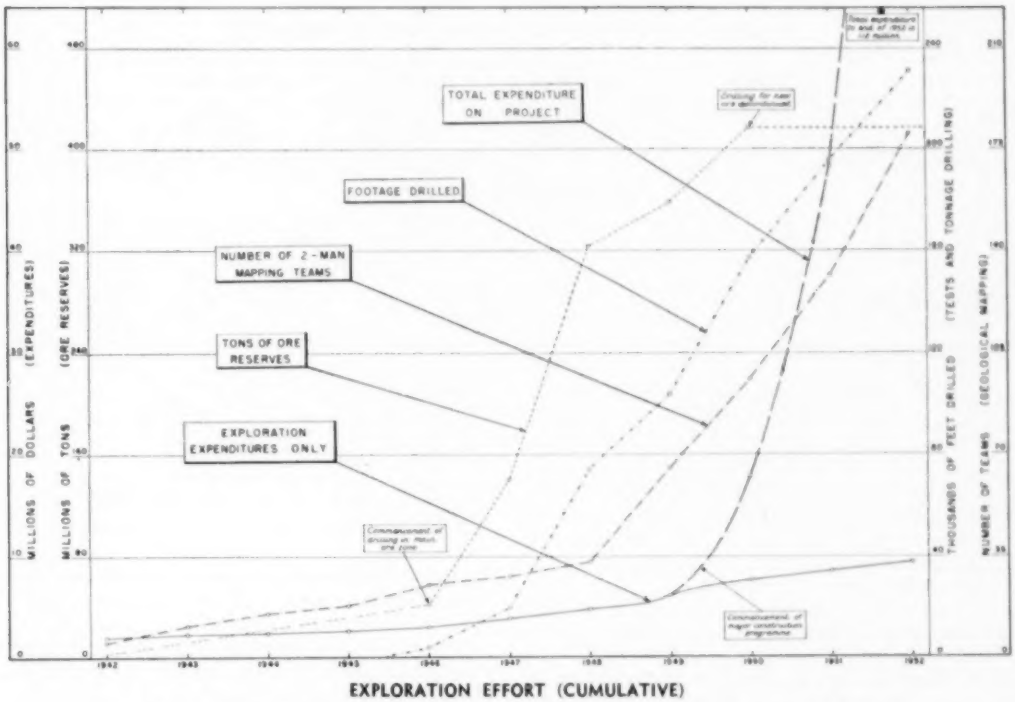
TOTAL EXPENDITURE ON PROJECT
FOOTAGE DRILLED
NUMBER OF 2-MAN MAPPING TEAMS
TONS OF ORE RESERVES
EXPLORATION EXPENDITURES ONLY
MILLIONS OF DOLLARS (EXPENDITURES)
MILLIONS OF TONS (ORE RESERVES)
THOUSANDS OF FEET DRILLED (TESTS AND TONNAGE DRILLING)
NUMBER OF TEAMS (GEOLOGICAL MAPPING)
EXPLORATION EFFORT (CUMULATIVE)

Fig. 7b—The most important economic results of this exploration are given in Table II.

Brunton compasses, dip needles, tachymeters, base maps, aerial photographs, and drafting equipment. Geological information is transferred nightly from aerial photographs and field note books to base maps so that the progress of the work can be readily followed by supervising geologists.

A valuable innovation is a field manual for party chiefs. It consists of some 90 pages and many illustrations covering such subjects as the general geology of the district, including the stratigraphy, structure, and lithology of the rock types; standardized legends and procedures to be used in preparing field notes, maps, and reports; the economic aspects of iron ore geology; and the procedure to be followed when investigating ore showings, as well as an outline of the duties and responsibilities of the party chiefs.

Monthly reports on field operations are prepared by the chief geologist for the consulting geologist and other Montreal and Cleveland personnel. Monthly reports on expenditures and comparisons with budget estimates are prepared by the accounting department.

Exploration and geological policies and programs are under the general supervision of J. K. Gustafson, consulting geologist of the M. A. Hanna Co. Field operations with A. E. Moss in charge are under the operating direction of the manager of mines of Iron Ore Co. of Canada, C. E. McManus.

The cycle of exploration activity in a typical year runs as follows:

1—In December the consulting geologist, after discussing the general scope and cost of proposed exploration for the coming year with the president of Iron Ore Co. of Canada, spends several days at Montreal with the chief geologist and his staff. The previous season's work is reviewed and the results appraised. The coming season's work is planned in detail, and tentative programs 2 to 3 years hence are drawn up. After discussing the program with the general manager and manager of mines, the consulting geologist prepares a memorandum summarizing work decided on.

2—The chief geologist guided by this memorandum prepares detailed lists of personnel, equipment, and supplies required. An estimate of cash requirements by quarters for the following year is drafted after consultations with the manager of mines, the manager of the subsidiary flying organization, the accounting department, and other company personnel.

3—The consulting geologist reviews and revises the figures with the chief geologist before recommending them to the president and board of directors for formal approval at their annual meeting.

4—In December the chief geologist begins hiring key personnel for the summer operations. Geologists, engineers, and prospectors are usually signed up by February 1st. Other personnel such as drillers, tractor drivers, shovel operators, mechanics, cooks, and clerks are indicated to other departments for hiring. Flying requirements are finalized with the manager of the flying company. Such projects as aerial photography and aerial geophysical work are contracted for.

5—Field work usually begins as soon as the waterways are free from ice around June 15th and continues until the end of September. The operating season once mining starts will be from May until October and is expected to average 5½ to 6 months. Field parties disband, and the permanent staff returns to Montreal early in October.

6—During the first six weeks in Montreal the year-round staff prepares final maps and reports of

Table II. Iron Ore Reserves, in Long Tons, December 1950

	Deposits	Bessemer	Non-Bessemer	Manganiferous	Total
Quebec	25	149,610,000	91,367,000	40,045,000	281,022,000
Labrador	19	78,298,000	45,066,000	13,321,000	136,685,000
Combined Totals	44	227,908,000	136,433,000	53,366,000	417,707,000

Average Grades, Dry Analyses

	Fe	Mn	P	SiO_2	CaO	MgO	Al_2O_3	S	Loss
Bessemer	60.73	0.29	0.027	8.71	0.09	0.05	0.59	0.012	2.88
Non-Bessemer	57.53	0.57	0.118	8.07	0.12	0.06	1.47	0.014	6.34
Combined Bess. & Non-Bess.	59.53	0.40	0.061	8.47	0.11	0.06	0.92	0.013	4.18
Manganiferous	50.17	7.64	0.109	7.92	0.10	0.06	1.32	0.012	6.65

field activities. Before December 1st party chiefs employed on a seasonal basis submit final reports and maps covering their areas. Their data are transferred, correlated, and interpreted on master geological plans which are constantly revised. Other winter activities include preparing maps and reports for the Quebec and Newfoundland governments, furnishing information to associated companies, and calculating ore reserves.

Although the attack on new territory has varied the sequence of events in most places has been as follows:

1—Rapid reconnaissance mapping by 2-man parties on a scale of ½ mile to 1 in. along the shorelines of waterways with occasional inland traverses to establish broad geological features.

2—Geological outcrop mapping on a scale of ½ mile to 1 in. along traverses spaced at half-mile intervals by 5 and 7-man parties and cursory examination of most of the iron formation. Two-man teams prospect the most favorable belts concurrently with, immediately preceding, or following this mapping.

Table III. Mapping Completed in Labrador-Quebec Iron Ore District

Scale	Area Mapped, Square Miles
1 in. equals 200 ft	135
1 in. equals 1000 ft	2,610
1 in. equals ½ mile	4,460
Reconnaissance	7,715
Total	14,920

3—Geological outcrop mapping on a scale of 1000 ft to 1 in. of all areas containing bands of iron formation. Traverses are spaced at 500 or 1000-ft intervals depending on local conditions. Practically all outcrops of iron formation are mapped except in areas containing abundant exposures. These areas are usually covered by a second or even a third group of prospectors.

4—Ore deposits and formation containing considerable leaching or enrichment are mapped on 200 ft to 1 in. During this detailed mapping, or immediately following, favorable areas are test-pitted or, where the overburden exceeds 15 ft, test-drilled to delineate orebodies.

5—Preliminary tonnage drilling of orebodies is undertaken and ore reserves calculated.

6—Prior to preparing pit layouts the orebody is mapped on a scale of 100 ft to the inch and continuous surface trenches excavated at right angles to the strike at 200 to 300-ft intervals. The ore is sampled and analysed. Bulk samples are secured from trenches or from 50 to 100-ft vertical exploratory shafts for testing the physical properties of the ore. Pit outline drilling follows.

Summary of Geological Effort

Figs. 7a and 7b give a quick measure of the geological and other exploration effort in recent years. The most important measurable economic results of this effort are given in Table II, a summary of the grade and tonnage estimates.

Some data not adaptable to graphic presentation may be of interest. The surface area of the 1500 current tracings on file exceeds 10,000 sq ft. This figure does not include field or preliminary maps or the hundreds of plans and sections which have become obsolete. The number of prints made from these originals would undoubtedly exceed 5000. Mapping completed to date is summarized in Table III.

It must be remembered that most of the area mapped on the 200 scale was originally mapped on 1000 scale, most of the area mapped on 1000 scale was originally mapped on the half-mile scale, and so forth. The Dominion government has photographed nearly all of the 25,000 square miles on a scale of ½ mile to the inch, while the Iron Ore Co. and concession companies have had over 3600 square miles photographed on 1000 ft to 1 in. and 500 square miles photographed on other scales. Nearly 40,000 aerial photographic prints are in company files. Fifty-two 2-man prospecting teams have prospected in the area since 1942. Many thousands of test pits have been dug and 231,000 ft of drilling completed. Approximately $10 million were spent on the exploratory phase of this project.

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Design Development of Crushing Cavities

by H. M. Zoerb

Based on the belief that operating details are a definite contributing factor to major economies, this paper traces the development of crushing cavity design in Symons cone crushers to attain maximum liner utilization. Wear rates are analyzed and compared in this presentation and drawings illustrate succeeding design changes.

IN these times of rising labor and material costs, it has become more and more necessary that attention be paid to some operating details which, in their obscurity, may be the key to major economies. Liner wear in crushing cavities of secondary and tertiary crushers can become an appreciable cost item when the material to be crushed is hard and abrasive. This item of cost not only includes the value of the crushing members, but also more intangible costs such as labor and lost production due to more frequent replacement.

The variables which are encountered in ores and minerals to be reduced; the design of plant and machine application; the sizes, shape, and fineness, characteristics of the crushed product; the moisture; hardness; friability; and abrasiveness of the material to be crushed are all influencing factors which must be taken into consideration in the selection of a crusher, and particularly in the design of crushing cavity and liners to be used in a crusher. Through a research program undertaken in cooperation with many operators of Symons cone crushers a new approach to crusher cavity design was made, resulting in the development of liners for specific operations which showed: 1—maximum utilization, as high as 70 to 80 pct of original weight of metal, and 2—maximum capacity of unit during the greater portion of its life. It has been found that liners so designed for a given operation will show added economies in power consumption, maintenance, and general wear and tear on the crushing unit.

Initial work in the so-called tailoring of crushing cavities was begun on the tertiary or fine crushing units where as a rule reduction ratios were low, varying from 3 to 6. Parallel or sizing zones in the lower portion of the crushing cavity were too long, resulting in a tendency to pack. It was found that very little additional crushing was done in the parallel zone after the initial impact in that zone and that a relatively small amount of additional crushing was done by attrition, which required very careful feed control. A small amount of over-feeding would result in packing which not only consumed power but caused unnecessary liner wear as well. The illustrations which follow in this discussion will show only contours of crushing cavities, and for purposes of simplification the cavities will be considered only in their closed position.

The first step, therefore, was to reduce the sizing zone to a minimum. This was done by removing the lower portion of the liner as shown in Fig. 1. The result of the change was a saving of 15 to 20 pct in liner cost, less power consumption, with no change in capacity.

This change in design, while an improvement, did not go far enough. As wear took place, the change in the liner was not uniform throughout its entire length, resulting in a restriction of the feed opening and thereby loss of capacity. Furthermore, progressive wear of the liner had the effect of lengthening the parallel zone until finally the entire crushing cavity was all parallel zone, see Fig. 2. It is obvious from the reduced feed opening of the worn liner that the ability of the machine to receive material is lessened considerably. Furthermore, the long parallel zone with its worn, irregular profile did not operate at its highest efficiency.

The first attempt to overcome this difficulty was carried out on a 5½-ft crusher installed in a plant producing roofing granules. The material being crushed was a very hard graywacke and the crusher was closed-circuited with a screen having .232-in. slotted openings. A radical change in contour was developed, as illustrated in Fig. 3. Equal wear lines on both concave and mantle are designated 1, 2, 3, etc. The method of development of this contour is as follows: Since adjustment for wear is vertical, corresponding intersections of wear lines and vertical lines developed concave and mantle contours which maintained equal but lengthening wear surfaces in the parallel zone. The ideal contour, of course, is one in which the length of the parallel zone remains constant, but because of present foundry practice and heat treating characteristics this is impossible.

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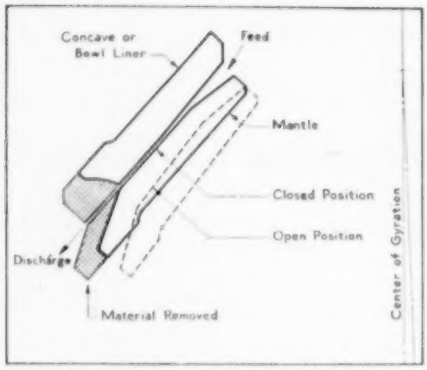

Fig. 1—Section through concave and mantle showing crushing cavity. Sizing zone was reduced to a minimum when lower portion of liner was removed as shown above.

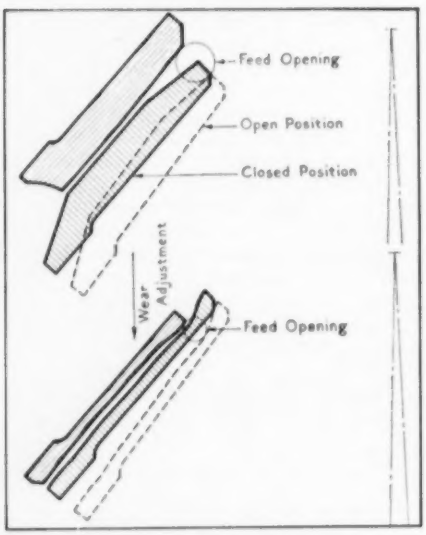

Fig. 2—Lengthening of parallel zone by progressive wear of liner. New liners are shown above, worn liners below.

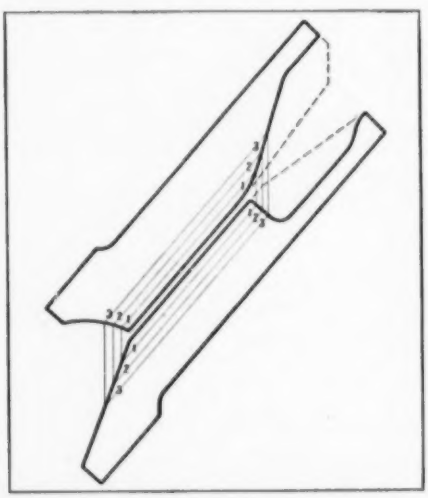

Fig. 3—Equal wear lines on concave and mantle, brought about by new design, are designated by numbered lines. Dotted lines show original contour of upper portion of crushing cavity.

The dotted lines of Fig. 3 show the original contour of the upper portion of the crushing cavity. It may be of interest to note here that the weight of the liners as redesigned was 2345 lb, or 32½ pct lighter than the original long liner illustrated in Fig. 1, and 15½ pct lighter than the conventional short-type liners which have been widely used the past ten years. The abrupt change in section on the mantle caused some concern as to performance, since it was possible that feed would be restricted. Actual performance, however, indicated that these fears were groundless. In fact, there was an advantage in that the rate of feed was controlled into the lower cavity, lessening the possibility of packing.

The result of the change is illustrated in Fig. 4. Solid lines show the worn sections of several contours superimposed upon the original. These contours were obtained by torching a section from the worn members and tracing the contour on a full size section of the original. It is to be noted that a surprising uniformity of wear was obtained. As nearly as can be ascertained, the average capacity increased from 90 to 104½ tons per hr, or 16 pct, and the total average tons crushed per set of liners increased from 71,000 to 84,000 tons, or 18 pct, in spite of the fact that the liners were 15.6 pct lighter. The rate of liner consumption was 0.062 lb per ton crushed as compared to 0.087 lb per ton crushed with the earlier design.

The possibility of this lighter design led to its adoption on other sizes of crushers. On this basis the following conclusions were drawn: 1—Application should be confined to operations involving a relatively small apparent reduction ratio, for example, up to 4. 2—In cases where the feed size was uniformly on the top side, a reduction in capacity would be found. This latter result was due to the restriction introduced by the ledge on the mantle, making the actual feed opening more sensitive to variation in the percentage of voids in the feed.

The next obvious step was to design a crushing cavity for a series of zones, each properly proportioned volumetrically, with proper distribution of metal which would yet result in an economical wear contour. Fig. 5 illustrates a cavity having three dis-

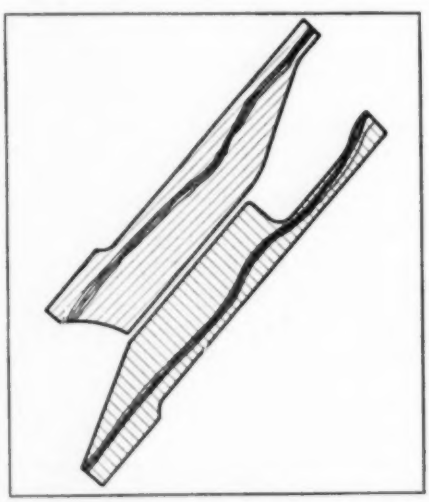

Fig. 4—Solid lines show worn sections of several contours superimposed upon the original. New designing increased average capacity from 90 to 104½ tons per hr.

tinct crushing zones, each zone developed according to the method described in connection with Fig. 3. This type of cavity, while still in the tertiary stage of reduction, permitted a greater range of reduction and was less sensitive to feed characteristics in so far as it affected capacity. Furthermore, the volumetric proportion of each succeeding zone required a lower degree of feed control.

An important consideration in the design of a crushing cavity of any gyratory type of crusher is that the angle of nip be held to a minimum. The use of the new design of cavity permitted this. In fact, as can be seen from the illustrations, the angle of nip over the work range of the crushing stroke is almost zero.

Because of the encouraging results obtained with the new type of cavity on tertiary crushers, the basic features were applied in a broader way in the secondary crushing stage. Apparent reduction ratios are generally greater here than in the third stage, although the actual difference is not great. A 12-in. nominal size feed from a primary will seldom have over 10 pct in the 10 to 12-in. size even when passed over a scalping device of reasonable openings. As a general rule, the bulk of the feed size is concentrated in the range above the scalping screen to approximately 60 pct of the top size. A crusher receiving a 12-in. top size feed with a 1-in. setting would then have an apparent reduction ratio of 12, although actually it probably would be 8 or less. It is this greater percentage of material which must receive most attention in the design of cavity and which naturally will be in the lower zones.

By applying the same methods as outlined in Fig. 3 and by departing gradually from the parallel condition above the lower zone, it has been possible to provide large receiving openings in a given machine and yet stay well below maximum nip angles. Furthermore, when the metal thickness of the wearing members is placed where it does the most work, a higher percentage of liner utilization can be obtained, see Fig. 6. A careful study of this problem has enabled us to provide a 7½-in. receiving opening on a 3-ft crusher at 1-in. setting, which was formerly the receiving opening of a 4-ft crusher. The

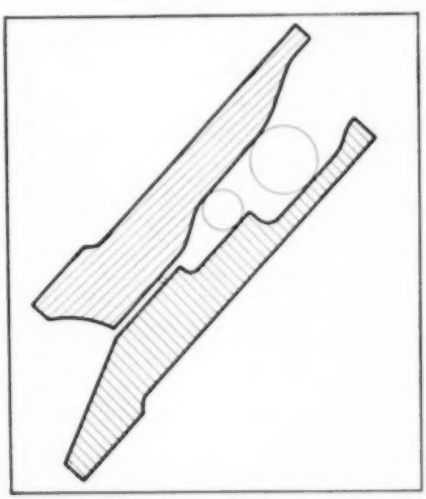

Fig. 5—This cavity, with three crushing zones, permitted greater range of reduction. The volumetric proportion of each succeeding zone required a lower degree of feed control.

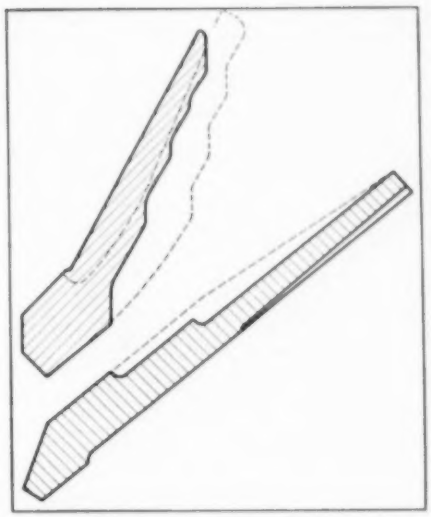

Fig. 6—When metal thickness of wearing members is placed where it does the most work, higher percentage of liner utilization is obtained.

4¼-ft machine can be supplied with a 12-in. opening, which is equivalent to a 5½-ft, and a 5½-ft cavity can be made with a receiving opening of 15 in., equivalent to a 7-ft machine. The 7-ft crusher, formerly limited to 15 in. at 1¼-in. setting, now can have a feed opening of 18 in.

Heretofore, it has frequently been necessary to recommend oversize crushing units to meet feed size limitations, particularly in the case of low-tonnage operations. The redesign of cavities, as outlined here, has permitted a better choice of crushing unit for the duty required, with lower first cost and more economical operation. The use of the so-called controlled feed cavity has enabled a large producer of limestone aggregate to standardize on two-stage crushing plants, producing all required sizes of aggregate except sand.

To date, more than 60 crushing units have been equipped with cavities embodying the features described above. With few exceptions they have been very successful, the exceptions being largely those where a wide range of crushing is done with a single unit. Experience has shown that there is no one type of cavity which will apply to all crushing operations, even though the reduction ratio may be approximately the same. Two crushing units operating in different plants, on different material, effecting the same reduction, may result in entirely different wear contours.

In large-tonnage operations, where the product and tonnage requirements are fairly constant, operating economies can be made by tailoring the crushing cavity to suit that particular condition. If liner wear can be reduced only 0.02 lb per ton crushed, a saving of approximately $75 per day can be made in a plant handling 10,000 tons. This is not impossible since it amounts to only 15 or 20 pct of many existing wear rates. It is a saving worth going after.

Further investigation remains to be done on this interesting phase of the crushing art. Much has been done in the development of wear-resistant materials and design improvements in grinding mill liners, but the gyratory type of crusher still presents an interesting challenge and until recent years has followed conventional features both as to cavity design and wearing member material.

Testing of Roof-Bolting Systems Installed In Concrete Beams

by Rudolph G. Wuerker

MUCH descriptive matter[1-20] has appeared on the subject of suspension roof supports, or roof bolting, as it is more commonly called. The widespread introduction of roof bolting into coal mines and metal mines is truly phenomenal. Mine operators were quick to recognize the advantages of supporting wide openings without hindrance to machine maneuverability and ventilation.

Although suspension roof support has long been installed at St. Joseph Lead Co. mines in southeast Missouri,[16] its application to coal mining presented new problems, such as proper anchorage and bearing for the bolts, bolt diameter, and spacing of bolts. After continuous testing and experimenting at the mines, standard roof-bolting materials were determined.[19]

The study reported in this paper is not concerned with such details as bolt diameter, which may be considered already solved in practice. In the tests discussed here, small models patterned on actual bolts were found to function in the same way and as satisfactorily as their prototypes. The aim of these tests was rather to investigate the influence of roof-bolting systems on the stress distribution around mine openings and to study the fracture patterns obtained in actual testing. Little was found about this in the literature, as testing of suspension roof methods and quantitative measurements are only now coming to the fore.

Several suggestions and actual measurements have been made to evaluate critically the functioning of roof bolting systems, single roof bolts, and parts thereof.[6, 21, 22] Outstanding among them is Bucky's outline of structural model tests.[20] Since none of the suggested testing equipment was available, however, for the experiments discussed below, a different approach was chosen.

The response of a mine roof under stress has often been compared to that of a beam. The slow coming down and bending through of beam or plate-like banks of shale, sandstone, or top coal is a familiar occurrence, extensively cited in the literature.[24] It was felt that testing of roof-bolt systems installed in a concrete beam which was loaded in bending would be a fair approximation of the behavior of a mine roof underground.

Another school of thought considers the roof behavior over an underground opening in connection with the stress distribution all around a circular or rectangular opening. This is more accurate, and leads to the concept of a dome-shaped zone of material destroyed under tensile stress. This is likewise a common sight in unsupported roadways where the continuous fall of roof results in what has been called the natural outline of roof fracture. This theory could not be tested and is treated separately in Appendix B.

It is important to note that according to both assumptions the immediate roof fails in tension; the use of a beam in these tests, therefore, should give information valid for either of the two theories.

With the testing equipment at hand it was possible to load concrete beams 6x1x0.5 ft under two-point loading, giving an equal bending moment over the center part in which the model bolts were installed. A comparison was made of the ultimate loads needed to break plain beams and beams in which roof bolts were installed. Arrangements were made with: 1—plain beams; 2—bolts with plate washers, some with holes drilled at 90° angles and others with holes drilled at 45° angles; 3—bolts with channel irons underneath; 4—bolts in holes filled afterward with cement; and 5—bolts anchored in a stronger stratum.

The foregoing arrangement is made in order of increasing strength, as assumed from the theory of reinforced concrete. Likewise, laminated beams with wooden model bolts and with combinations of the foregoing set-ups were tested. All in all, 21 experiments were made out of the much greater number of combinations possible. There were, too, some trial tests. Enough observations from this limited number were made to interpret the behavior of mine roof, supported by various types of suspension bolts, at fracture.

In present-day concepts, which have been proved by mathematical derivations and stress analyses, any opening driven underground will change the distribution and magnitude of the stresses existing around it. It does not matter whether the stresses become visible, as in rocks whose strength is less than the forces acting upon them, or whether they are invisible, as in the gangways lacking evidence of rock pressure. In this latter case the rocks can withstand changes in stress-distribution.

To consider the mine roof as a beam, there are, with transversal loading, tensile stresses in the lower fiber and compressive stresses in the upper layers above the neutral axis of the beam. Beams of brittle material such as rock and concrete fail exactly as shown in Fig. 1. Nearly all model beams showed the same fracture pattern as that of a tension crack. The influence of support, by roof bolting or conventional

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props, is shown in Fig. 2. Any support has two functions. First, it contributes to the reduction of stresses, as is evidenced by the reduced span of the unsupported rock in Fig. 2. Secondly, it bears the deadweight of the loosened rock. It is obvious that the stronger the support, the more the stresses will be reduced.

At this point further clarification is needed on the different meanings given to the same strength terms used in many discussions of roof bolting. A distinction should be made, in discussing *strengthening* or *reinforcing* a mine roof, as to whether the increase is from a low collective strength to the highest value possible for this material, that is, from a laminated to a more competent beam, or whether it is a further increase from this point on, from a plain but competent beam to a still higher value, much as a concrete beam is reinforced by the installation of horizontal rods and vertical stirrups, see Fig. 3, lower half. The first case holds for all discussions of the benefit of using bolts on *lamination* of strata, and in the discussion in Appendix A it is shown that no strengthening of a laminated beam over and above the strength of the competent beam is possible. But this was not the aim of the tests, although two beams, No. 21 and 22, were cast in two halves each 6-in. high within an interval of two days. As the results were inconclusive this was not followed up.

This distinction in the two different types of beams is reflected by using the term *bearing capacity* for laminated beams, in analogy to soil mechanics, and *strength* for competent beams to which the laws of elasticity can be applied.

The purpose of the experiments was explicitly to study the second step in increase, to discover whether or not the bolts would increase strength in the same way horizontal bars and stirrups increase the strength of the common reinforced concrete beam of the structural engineer.

Testing Procedure

In the tests, concrete beams 72 in. long, 12 in. high, and 6 in. deep were supported over a 64-in. span. A two-point loading was applied by a girder, whose loading points, P, were 32 in. apart. The girder in turn was pushed down by the head of the testing machine. Thus a constant bending moment throughout the center section was given. In this case, see Figs. 3 and 4, the maximum bending moment is $P\,a$, the maximum deflection

$$\Delta \max = \frac{P\,a\,(3l^2 - 4a^2)}{24\,E\,I} \qquad [1]$$

wherein

Δ max = maximum deflection, in.
P = load, lb (Note that the load exerted by the plunger of the testing machine equals $2P$.)
l = total span of beam, in.
a = distance between support and load, in.
E = modulus of elasticity in bending, psi
I = moment of inertia, in.^{4}

From the moment diagram, Fig. 4, it can be seen that there is an equally distributed load between points BC, where the loads act and between which the model roof bolts were installed. Within this 32-in. part of the beam four holes were drilled 9 1/3 in. apart, some at an angle of 90°, some at 45°, so that it was possible to test all roof-bolting systems either of steel or wood with varying anchorage or with plates or ties under the tension side of the beam. The plain beams were broken first and the relative increase in strength was sought, as expressed in higher loads on the plunger of the testing machine, and as caused by the roof-bolting systems.

Preparation of Concrete: The beams were cast with concrete of a ratio, by weight, of 3.5 parts sand to 1 part cement to 0.53 parts water, the last value containing 1.5 pct free moisture of the wet sand. This ratio was chosen as being close to the tensile strength of roof shale previously determined by extensive testing. The maximum size of the sand, which met all the standard ASTM specifications, was ¼-in.

Through the cooperation of the management of the Murdock Mine of the Bell and Zoller Coal and Mining Co., Murdock, Ill., samples of shale from roof fall had been obtained that could be taken as typical for a mine roof over Illinois seam No. 7. Tensile strength of this shale was determined by a method similar to the ASTM standard C-190-44 for hydraulic cement mortar and by means of Riehle cement briquet testing machine. Average value obtained was 770 psi. The specimens, however, were cut from sound shale banks that might not be representative for the collective strength of this particular shale roof, which is full of bedding planes and shear cracks.

But a concrete of such high tensile strength is not common. The above-mentioned mixture is the result of a great many tests to approach the value of the tensile strength of the roof shale. Only a few specimens reached an 800-psi tensile strength at an age of 2 to 3 months. Three tensile specimens were prepared separately on the day of casting of each beam, following ASTM Standard C 190, and tested the same day in the Riehle briquet tensile test machine. Likewise, separate 2x4 in. cylinders for compression tests were set aside the day of casting of a beam, and compressive strength determined at the day of breaking the beam.

All beams, tensile and compression specimens, were moist-stored at a temperature of 70°F for 28 days, and then taken out for drilling holes, installing the bolts, and testing. The holes were 10 in. deep and were drilled with a ⅜-in. drill. In simulating underground conditions, drilling was favored over precasting, since drilling a hole may weaken the rock and act as a stress-concentrator.

Preparation of Steel Roof Bolts: The model steel bolts, shown in Fig. 5 with all accessories, were of 5/16-in. cold-rolled, round steel with a tensile strength of 60,000 psi at the proportional limit. They were 1/16-in. less in diam than the hole. The torque applied to the bolts was 20 ft-lb. Afterwards the individual bolts at each broken beam were tested with a torque-wrench. It was found that the wedge anchorage was sufficient and that the bolts were sheared off in or just above the threads at torques of 20 to 25 ft-lb.

Preparation of Wooden Roof Bolts: The pertinent data concerning wooden model bolts, washers, and plates, made of red oak, is given in Fig. 6.

Twelve specimens of the oak wood, used for the wooden roof bolts, were tested in tension. The extreme and average values obtained are shown in Table I.

Single and double shear strength of the red oak was determined by means of a conventional fixture for testing metals in shear. Load was applied normal and parallel to growth rings. This distinction need

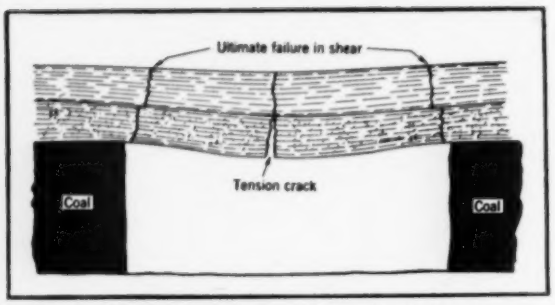

Fig. 1—Action of immediate roof preceding failure (from U. S. Bur. Mines Handbook: *Questions and Answers on Roof Support in Bituminous Coal*).

not be made with roof bolts underground, however, and the following statistics are therefore listed: lowest value, 4700 psi; highest value, 5330 psi; average value, 5045 psi. It should be mentioned that double shear gave about twice the above values, as was to be expected.

Test Results of the Material: In spite of all precautions taken, very few definite strength and elastic values of the concrete were obtained. Concrete, however, behaves much like sedimentary rocks of mine roof. Concrete is, according to data available, weaker than shales, schists, and sandstones, but as it can be formed to almost any shape it is an ideal material for testing of sedimentary rocks. Some strength and elastic properties of concrete increase with age, as can be seen in Table II, columns 4 and 5 for compressive strength and columns 4 and 6 for tensile strength. In the case of the tensile property, an increase in tensile strength with age from about 400 psi for specimens 23 and 24, of 22 and 25 days age respectively, to 550 to 600 psi as average for specimens older than 28 days is within expectations. The compressive strength of the separate specimens, which is needed for computing the modulus of elasticity, showed a slight increase with age. Abram's formula $S_{compr.} = \frac{14{,}000}{7\left(\frac{w}{c}\right)}$ wherein $\frac{w}{c}$ is the water-cement ratio by volume, seems to coincide with the arithmetic mean of all compressive strength values plotted. Its numerical value in the present case was 6230 psi. However, in bending no increase of strength with age is assumed after 28 days, rather, a slight decrease; thus age need not be considered a variable in testing work.

Test Results of Roof Bolting Systems: Whereas four repetition tests could be made with plain beams, this number of tests for each possible arrangement would have been too costly and time-consuming. Duplicate tests were run only for the most common arrangements: 90° holes with plate washer under, 90° holes with channel iron under, and 90° holes with plate washer but with anchorage in a stronger stratum. This last arrangement was effected by opening up the beam from top, putting a ring washer under the wedge and closing the hole in the beam again with a quick-setting cement or a mixture of cement and plaster of paris.

All other tests were made with a single specimen. They might or might not be representative for that special bolt installation, giving a value either too high or too low, similar to the wide spread of strength properties of concrete in plain beams.

Table I. Results of Parallel-to-Grain Tension Tests of Red Oak

Item	Moisture Content, Pct	Sp Gr	Modulus of Elasticity, Psi	Ultimate Tensile Strength, Psi
Lowest value	8.5	0.72	2,258,000	16,230
Highest value	8.2	0.69	2,459,000	30,890
Average value	8.5	0.70	2,347,000	22,990

The complete test results are listed in Table II. The most important data is found in column 3, Description of Beams, and column 11, Type of Failure. The behavior of a special roof-bolting system at or after the fracture of the beam can here be seen quickly. The ultimate load exerted by the plunger of the testing machine is listed in column 10. This value is equivalent to 2*P*, *P* being used as in Figs. 3 and 4.

The strength data of separate test specimens is likewise given. The average compressive strength and the modulus of elasticity derived therefrom are found in columns 5 and 8 respectively. Average tensile strength of separate specimens is listed in column 6, and data pertaining to the beams in column 7, Modulus of Rupture, and column 9, Modulus of Elasticity in Bending. An interesting

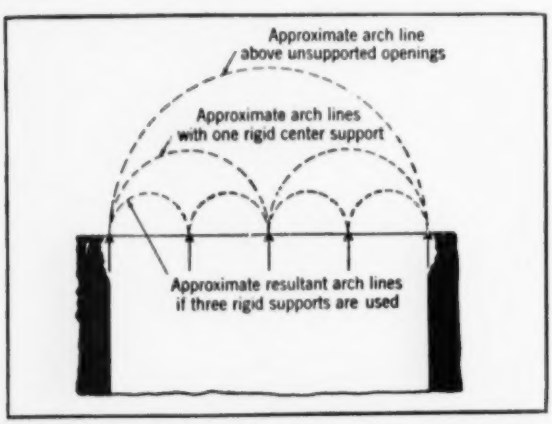
Approximate arch line above unsupported openings
Approximate arch lines with one rigid center support
Approximate resultant arch lines if three rigid supports are used

Fig. 2—Approximate arch lines above opening (from U. S. Bur. Mines Handbook: *Questions and Answers on Roof Support in Bituminous Coal.*)

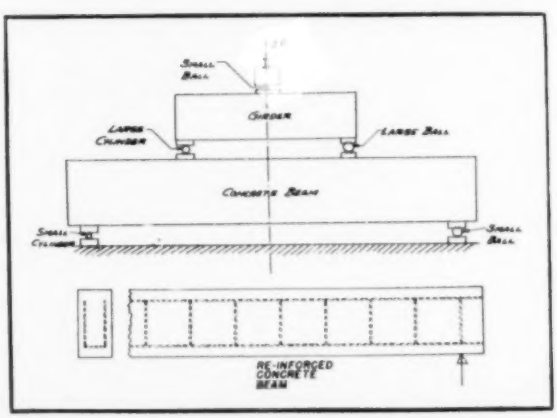

Fig. 3 (Upper)—Arrangement for testing roof bolting systems in concrete beams, and (lower)—reinforced concrete beam.

Table II. Tests of Roof-Bolting Systems Installed in Concrete Beams

1 Exp. No.	2 Beam No.	3 Description of Beams	4 Age on Date of Test (Days)	5 Avg. Compr. Strength on Date of Test (Psi)	6 Avg. Tensile Strength on Date of Test (Psi)	7 Modulus of Rupture from Bending (Psi)	8 Modulus of Elasticity in Compr., Expr. (10^6 Psi)	9 Modulus of Elasticity in Bending, Expr. (10^6 Psi)	10 Load at Failure, Lb	11 Type of Failure	12 Bolt Arrangement and Location of Failure
1	13	Plain	36	7775	567	236	2.045	3.16	4250	Tension	
2	14	Plain	36	8500	667	139	1.530	1.08	2500	Tension	
3	23	Plain	25	5493	450	278	1.842	1.290	5000	Tension	
4	24	Plain	22	4803	366	263	0.928	1.59	4750	Tension	
5	10	Holes, but no bolts	40	6910	478	200	1.285	0.980	3600	Between holes 2 and 3	
6	3	Steel bolts, 5/16-in.	50	4800	579.2	264	1.275	1.37	4750	Through hole 3	
7	4	Steel bolts, 5/16-in.	78	5560	568	292	1.000	2.28	5250	Through hole 2	
8	1	Steel bolts, 5/16-in.	64	4500	538	250	1.010	0.892	4500	Through hole 2	
9	5	Steel bolts, 5/16-in.	43	3940	748.3	306	1.720	1.630	5500	Shear outside	
10	11	Steel bolts, 5/16-in.	64	6350	750	322	1.290	2.180	5800	Shear outside	
11	7	Steel bolts, 5/16-in.	78	7500	800	300	1.194	1.570	5400	Tension, through hole 1	
12	12	Steel bolts, 5/16-in.	64	7950	770	356	1.389	2.52	6400	Between 1 and 2	
13	6	Steel bolts, 5/16-in.	92	6950	732	333	1.171	1.45	6000	Shear through 1 at top	
14	19	Steel bolts, 5/16-in., inserted on casting	43	8040	533	272	1.310	1.52	4900	Tension between 3 and 4	
15	20	Steel bolts, 5/16-in., inserted on casting	43	7400	568	372	1.150	1.210	6700	Through 2	
16	21	Steel bolts, 5/16-in., laminated beam	46	5696	488	221	1.272	1.650	4000	Through 3	
17	22	Steel bolts, 5/16-in., laminated beam	46	6015	505	278	1.613	1.360	5000	Through 1	
18	9	Wooden bolts, 3/8-in.	89	6896	266	400	2.000	1.770	7200	Between 1 and 2	
19	15	Wooden bolts, 3/8-in.	32	4160	653	333	0.722	1.54	6000	Between 2 and 3	
20	18	Wooden bolts, 3/8-in.	53	8770	588	278	2.545	1.14	5000	Between 1 and 2	
21	16	Wooden bolts, 3/8-in.	46	5600	700	333	1.120	2.18	6000	Tension through hole 3	

* Fracture outside bolted area.
** Beam still held together.

observation as to the validity of the laws of elasticity, on which the experiments were based, can be made here. For plain beams, 1 to 4, the values of columns 6 and 7, Tensile Strength and Modulus of Rupture, and the values of columns 8 and 9, Elasticity in Compression and Bending Test, should show better agreement. The same spread of experimental data could be observed in the breaking load of the plain beams in column 10. In testing brittle materials such as concrete or rock the experimenter must be satisfied with the fact that strength data are rarely definite but will spread over a certain band. For this reason no other measured or computed data is listed, although many more are available. The experiment was, except for the nature of the material, well under control. A further improvement, like installing strain gages on the bolts, would be worth following up.

Interpretation of the Test Results. Increase in Strength: In an evaluation of test results, see Fig. 7, breaking load is plotted as a function of increase in reinforcement. As the arrangement of increasing effectiveness of the various roof-bolting measures is a somewhat arbitrary procedure, the five steps previously mentioned were followed, namely: 1—plain beams, 2—roof bolts with plates only, 3—with headers or channel irons under, 4—with better bond between steel and concrete, and 5—better anchorage, which was brought about in the tests by the placing of a washer under the inner wedge in imitation of actual roof bolts anchored in a stratum stronger than the immediate roof. As some of the beams contained overlapping properties, this way of plotting could hardly be carried any further, but the contribution to increasing strength is clearly evident in Fig. 7.

Failure Pattern: More convincing conclusions could be drawn from the study of the fracture patterns, shown by symbols in column 12 of Table II. Out of 17 tests with bolts, six beams failed through 90° holes, six with tension cracks between the 90° holes. Two beams cracked through, but not along 45° holes, and three broke outside the bolt system. The following results stand out.

1—All the beams which had a channel iron connecting the bolts at the bottom of the beam, that is, No. 9, 10, and 13, failed outside the bolts, and as a glance at Fig. 7 shows, had relative high strength values also. They were the only ones that did not break with a tension crack, but in a pattern that approached shear failure. The portion of the beam over the channel iron was apparently strengthened to such an extent that the fracture took place in the unsupported part. Another beneficial influence of the headers under the bolts could be observed in the case of experiments 20 and 21. Here the beam failed in tension within the bolting system, *but the broken beam was still held up by the header.* Applied to mining this would mean that fall of roof would be avoided or delayed until additional support could be put up.

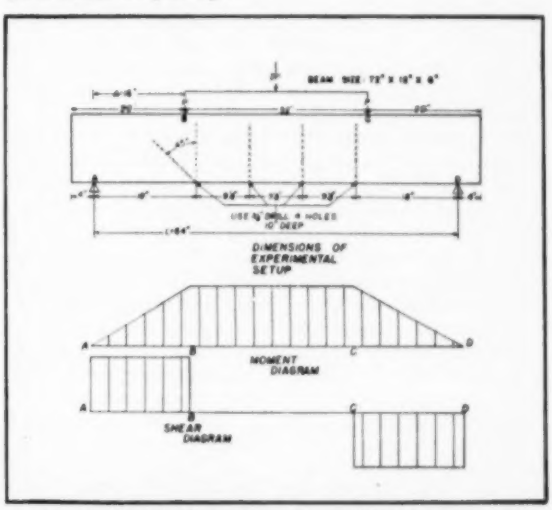

Fig. 4 (Upper)—Dimensions of experimental set-up, and (lower)—shear and moment diagram.

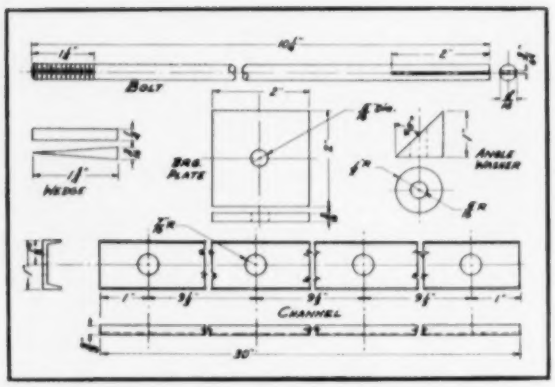

Fig. 5—Model steel roof bolt with accessories.

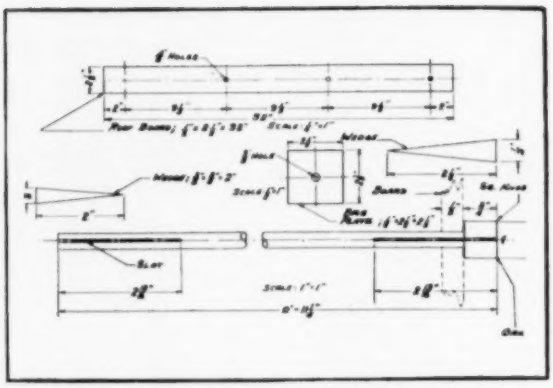

Fig. 6—Model wooden roof bolt with wedge, board, and plate.

2—This same effect of delaying roof fall was noted in cases where the beam fractured through a 45° hole, but at a different angle, see experiments 15 and 21. The broken beams were held together by the bolts in a way similar to the beams with roof bolts and headers. Roof fall in this case would also have been delayed.

3—The behavior of wooden roof bolts in the tests corresponded in all respects to that of steel bolts. On Fig. 7 the wooden bolts, beam numbers 9, 15, and 16, all can be found in the upper range of breaking loads. The failure behavior showed that the wooden bolts and boards would have sufficient strength to hold broken roof portions about to fall.

To summarize, on the assumption that suspension support aims mainly at reducing the extension of the zone of destroyed material, it can do so only if it can strengthen the immediate roof.

Influence of Vertical and Lateral Reinforcement: It is evident that the greatest disadvantage of bolting is the gap formed between the wall of the drilled hole and the roof bolt. If the roof in flexure bends through, the material will move into the space left between bolt and circumference and in doing so has already lost its cohesion. This explains why 50 pct of the tested bolts with 90° hole and plate under cracked through the hole. The holes acted as stress-concentrators.

Although the strengthening effect brought about by the bolts in the other 50 pct of the beams was sufficient to overcome this detrimental effect, it was not sufficient to strengthen the beam laterally. The beams cracked between the holes. These shortcomings can be overcome by the following measures, listed in their rank of efficiency: 1—roof bolt having the full diameter of the hole, as in the case of wooden bolts. 2—high friction between bolt and rock, as with the wooden bolt, or the steel bolt, if it is the deformed reinforcing round bar type. 3—perfect bond between bolt and wall of hole. This is the mine operator's intention when he injects cement in the gap between bolt and rock. The technical and economic limitations of this method are obvious.

The above procedures might bring about vertical reinforcement, but their effect in a horizontal direction seems insufficient. This was brought out by the experiments in which one half of the bolted beams failed in between the holes. This can be observed underground on certain shale roofs, see Fig. 8. In soft shale roof, fortunately not common, the rock falls out around the bolt supported by the plate only and tapered upward. This failure pattern is certainly a good example of the stress distribution around a vertical bolt. The similarity with the theoretical arch lines above a supported mine opening in Fig. 2 is indeed striking. The same phenomenon has been observed by Cross and Price[3] in other mining areas.

A further conclusion can be drawn as to the advantage of lateral reinforcement. Only in the cases where channel irons and headers were installed was the lateral strengthening apparently sufficient to bring about higher breaking loads and to shift the plane of final fracture outside the stressed zone. A logical step from here on would be to install headers in the longitudinal axis of the roadway. At the face they would cover the unprotected area in much the way forepoling is used. A second step would be to make a still more complete *skin* by putting up a wire of ordinary fencing wire from bolt to bolt. This would certainly keep any loose rock from falling. Cross and Price,[3] carrying out their observations underground, arrived independently at the same suggestion.

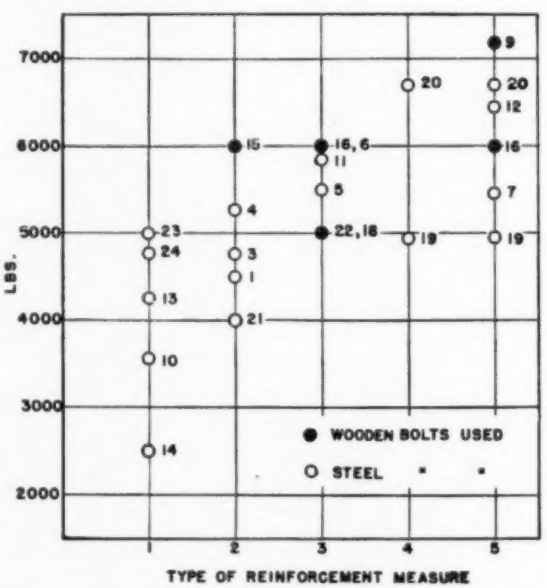

Fig. 7—Ultimate breaking load of concrete beams and roof bolts tested vs reinforcement measures, which are: 1—plain beams; 2—bolts not cemented in place, plates only; 3—channel iron, or board in the case of wooden bolts, on underside of beam; 4—bolts inserted in casting; 5—better anchorage. Numbers 1-24 refer to beam numbers given in Table II, column 2.

Fig. 8—Destruction of soft shale roof around roof bolts. Left, shale falls out around base plate and leaves a cone of rock supported by base plate. Center, enlarged view of base plate. Right, wooden blocks over base plate.

Influence of 45° Hole on Fracture: Because of the tendency of concrete beams to fail with a tensile crack and at a 90° angle, the beams with a 45° hole, see experiments 15 and 21, showed a certain advantage over the 90° hole in the sense that after failure the beam was still held up by the bolt. It could be reasoned that the holes could have been drilled in such a way that their projection would have fallen over the whole length of the beam, so that any crack would have to intersect a bolt. This is important when bolts are installed at a 90° angle and are held by plates.

Other roof rocks will certainly have a different fracture pattern; they will probably tend toward shear failure. If there is a prevalent tendency to break at a certain angle, it should be possible to set the holes and bolts so that they will intersect the preferred fracture planes. Another advantage of the 45° hole is that it allows the installation of longer bolts than the 90° hole, a fact which becomes of importance in the case of low seams.

Wood as Bolting Material: From the testing results and the foregoing considerations it is evident that wood meets most requirements outlined for an ideal roof bolt. Provided that no detrimental atmospheric and water conditions exist, the relative high strength of wood exerted by a much larger cross-sectional area comes into action. Using the value of 16,230 psi as tensile stress for wood and 30,000 psi for steel, a 1-in. steel bolt would sustain a load of 25,400 lb at the proportional limit, and 50,800 lb at the breaking point, in contrast to 88,000 lb taken up by the wood bolt at the proportional limit. The slotted ends of a wooden bolt, however, will probably fail before this value is reached.

A similar comparison applied to the shear behavior of the two materials gives a higher ultimate shear load to the steel bolt, in spite of its smaller cross-sectional area, by reason of the fact that the shear-strength of steel is about ten times that of red oak.

As wooden roof bolts can fill the hole drilled in the roof, they offer a further advantage. No initial movement of the rock into the hole seems to be possible, and a certain amount of friction can be assumed that might substitute for the bond between concrete and reinforcement postulated in the foregoing discussion.

Other Functions of Support: It should be borne in mind that stress or load is not the only factor influencing the strength of rock. Generally, the state of a material like rock can be explained as a function of the following five factors:[85] 1—load, in this paper only discussed; 2—stress history; 3—chemical and physical environment; 4—time; 5—temperature.

With sedimentary rocks, items 3 and 4 in particular often influence the behavior of roof and walls more than do the stresses set up in them. The exclusion of humid mine air has been described rightly in the literature as one of the most beneficial effects of roof bolting on the conservation of mine roof.

The influence of time on loading, often alluded to as *creep,* has not been stressed enough. While rock creeps at ordinary temperature, steel does not. Roof bolts will therefore stop the slow coming down of the roof so common in mining. This is caused by the fact that rocks will deform under loads much lower than the ultimate load, if the load is applied only over a period of days or weeks.[89-91]

Appendix A

Rewriting Eq. 1

$$\text{Maximum moment } Pa = \frac{\Delta_{max} \cdot 24 \cdot E \cdot I}{(3\,l^2 - 4a^2)}$$

$$P = \frac{1}{a} \frac{\Delta_{max} \cdot 24 \cdot E \cdot I}{(3\,l^2 - 4a^2)}$$

It becomes evident that the load required to break a beam increases if Δ_{max}, E, and I increase. The deflection Δ_{max} is not important here, and E is supposedly

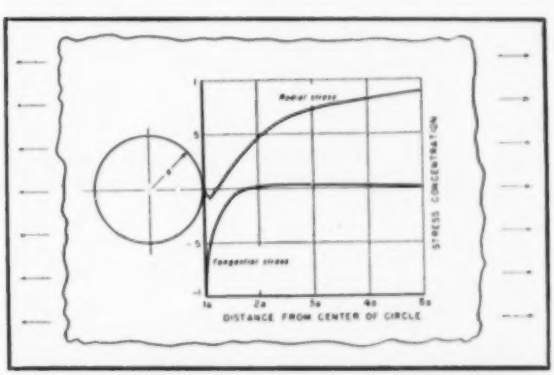

Fig. 9—An areal distribution of stress along vertical axis of symmetry for circular hole in infinite plate. Unidirectional stress field. (After Duval, U. S. Bur. Mines *R. I.* 4192).

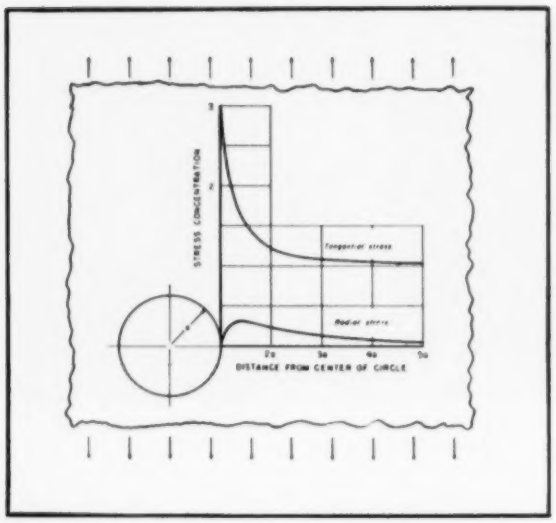

Fig. 10—An areal distribution of stress along horizontal axis of symmetry for circular hole in infinite plate. Unidirectional stress field. (After Duval, U. S. Bur. Mines *R. I.* 4192).

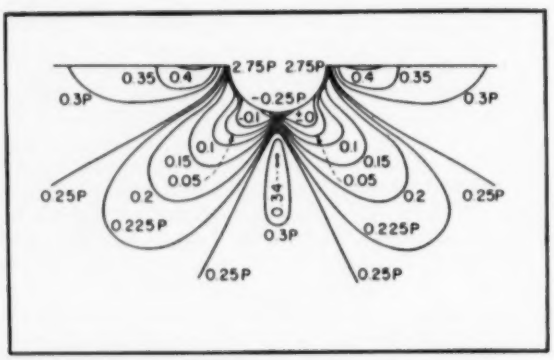

Fig. 11—Lines of equal stresses around lower half of circular opening. Positive values are compression stresses; negative values are tension. (After Wuerker, *Engineering and Mining Journal*, June 1949, p. 61).

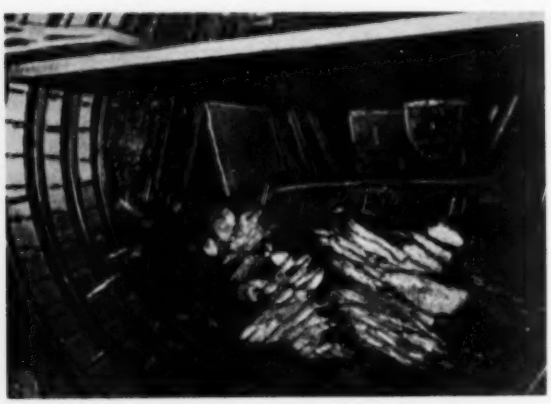

Fig. 12—Zone of destroyed and slaty material in floor of drift, similar to the stress distribution in Fig. 11. (After Wuerker, *Engineering and Mining Journal*, June 1949, p. 61).

a constant for any material. It could be argued that in suspension support E, of rock plus E, of the steel bolts would combine to a higher value than E,. This would be analogous to reinforced concrete, where E of the reinforced member is higher than E of the plain concrete. But in this latter case, steel and cement make a perfect bond. This does not take place with conventional roof bolts, as is discussed under *Influence of Vertical and Lateral Reinforcement*. This can be seen, too, by comparing the modulus of elasticity in compression, see column 8, Table II, with the modulus of elasticity in bending, column 9, Table II. If there were such an increase in strength properties, as is obtained by the steel bars in reinforced concrete, the modulus of elasticity in bending of the bolted beams should be much higher than the one in compression of the plain concrete. Whatever increases can be noted, they are not higher than the variation in properties inherent in a material like concrete.

The only quantity left that might influence P, then, is I.

$$I = \frac{bh^3}{12}$$

where b = width of beam or lamina and h = height of beam or lamina.

If a beam of the height h_b is made up of n laminae having the height h_l which is always a fraction of h_b, the best bond or lamination of all the laminae will never reach a height $\Sigma\, h_l$ greater than h_b.

Thus a strengthening of a laminated beam over and above the strength of a competent beam is impossible.

Appendix B

In the experiment, roof bolting systems were treated as reinforcements of a beam under transverse load. There is, however, a second school of thought that considers the changes in magnitude and distribution of stresses all around an underground opening. This is, no doubt, the more accurate view. The nature of these changes has been investigated by Love,[80] Mindlin,[83] Schoemaker,[84] and Wuerker.[85] Photoelastic tests[86] have shown very good agreement with the theoretical assumptions.

Figs. 9 and 10, as given by Duval,[27] explain best the point in view. Here the stress concentration, that is, the stress at any point divided by the average applied stress, around a circular opening in a unidirectional stress field is plotted against distance from center of hole. Fig. 9 shows the stress distribution along the vertical axis and Fig. 10 the stress distribution along the horizontal axis. In this latter case, the tangential stress produced on the boundary at the ends of the vertical axis is equal in magnitude but of opposite sign to the applied stress. Thus if the applied stress is a compression, this stress is a tension. Failure of rock occurs, therefore, in the roof and floor rather than in the side walls, as the tensile strength of most rock is only a very small fraction of the compressive strength.

This is the explanation for the formation of the well-known *dome* over openings, which is a zone of rock so destroyed by tensile stresses that all coherence is lost and the roof starts falling. If lines are plotted of equal stress around the circular opening, a stress distribution as shown in Fig. 11 results, giving lines of equal principal stresses with the secondary stresses suppressed. (A symmetrical identical pattern exists over the upper half of the roadway.) Negative tensile values can be seen at the top and bottom of the opening.

Fig. 13—Formation of *dome* in roof of roadway. (After Wuerker, *Engineering and Mining Journal*, June 1949, p. 60).

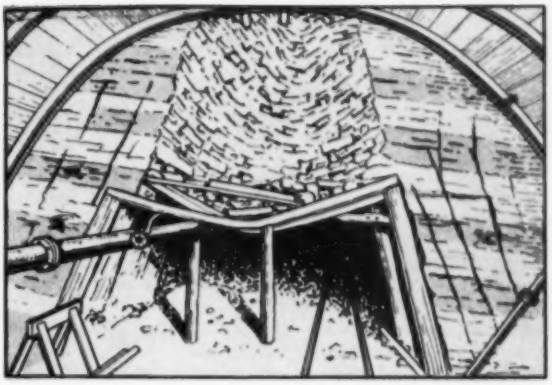

Fig. 14—Reproduction of Fig. 13 to show zone of crushed rock in the dome over the square set. (After Wuerker, *Engineering and Mining Journal*, June 1949, p. 60.)

Both Figs. 12 and 13 are photographs which were taken underground. They show the formation of *domes* in the roof and floor of a country rock. Original bedding planes can be seen from the lighter and darker bands in Fig. 14 and are shown dipping about 10° toward the right. The conformity with the stress-analytical picture is indeed convincing.

Roof bolting, as practiced in our coal mines, does not concern stress all around the openings. Should need for this arise, probably in very deep mines, it would be sufficient to strengthen the immediate roof and sidewalls to such an extent that the stress concentration of $3P$, see Fig. 11, is taken care of. This takes place in a zone with a radius of $2a$, distance a being equal to the radius in the case of circular opening. In other words, roof bolts should have at least the length a in this example.

Acknowledgments

This testing work has been carried on by the Department of Mining and Metallurgical Engineering with the cooperation of the Department of Theoretical and Applied Mechanics of the University of Illinois, as part of the work of the Engineering Experiment Station of this university. Professor H. L. Walker, head of the first-named department, has given all support possible to the project. The Department of Theoretical and Applied Mechanics took charge of preparing tensile and compression samples of concrete beams and of preparing special fixtures for the test. The great help given in this phase by Assistant Professor C. E. Kessler, in charge of the Concrete Laboratory, and by his staff and shop personnel is gratefully acknowledged.

The Department of Mining and Metallurgical Engineering prepared the models of the various roof bolts, installed them, and ran the tests. Credit is due Messrs. N. Szabo and, especially, S. J. Jachim, who did most of the preparing and executing of the tests. Former students B. W. Gilbert, A. Risi, and J. W. Snarr helped during the actual tests and did most of the recording, plotting, and computing of experimental data. In this part of the work the shop personnel of the Department of Mining and Metallurgical Engineering under H. W. Kruse, Senior Laboratory Mechanic, helped readily and most efficiently so that the experiments could be carried out on the rigid schedule prescribed by the change in strength properties of concrete with age.

Supplementary work was carried out by G. M. Hunt, Director, Forest Products Laboratory, U. S. Forest Service, Madison, Wis., and his staff in determining some strength values of the wood used in wooden roof bolts.

The manuscript was read by Assistant Professor C. E. Kessler, Department of Theoretical and Applied Mechanics, by Associate Professor G. B. Clark, Department of Mining and Metallurgical Engineering, and by T. E. Coleman, Jr., Assistant in English and in Metallurgical Engineering; their various suggestions are gratefully acknowledged.

The author was in charge of general planning and supervision, as well as the writing of this report.

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Reducing the Moisture Content and Large Moisture Variations in Russellton Washed Coal

by Orville R. Lyons

THE Russellton preparation plant of Republic Steel Corp., located north of Pittsburgh, Pa., prepares 3½x0-in. Thick-Freeport coal by means of a 13-ft 6-in. diam Chance cone and 16 No. 7 Deister tables. The plant feed ranges between 370 and 410 tons per hr, of which approximately 31 pct is ¼x0-in. size, and the plant reject ranges between 14 and 16 pct of the feed.

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The 3½x¼-in. washed coal, the cone product, is dewatered and desanded by a double-deck Parrish-type shaking screen 46 ft long and 7 ft wide. The 1½x¼-in. portion is further dewatered by two 4x12-ft single-deck vibrating screens. The ¼x0-in. washed coal from the tables is distributed to three 54x70 in. Bird centrifuges. The dewatered centrifuge product is combined with the product of the dewatering screens prior to loading into railroad cars.

During the early part of 1951 complaints were received from officials at Republic's coke ovens concerning the moisture content of Russellton washed coal. The records revealed that during the first half of 1951 the shipped washed coal moisture averaged

7.03 pct and that daily moistures fluctuated from 5.35 to 9.67 pct.

The coke oven officials asked for a washed coal averaging less than 6 pct moisture and a top limit of 6 pct moisture. These requirements could not be met, in toto, without reducing the output of washed coal, or, as an alternative, adding additional dewatering and possibly thermal drying equipment to the plant. A compromise goal was finally established of providing a washed coal averaging 6 pct or less moisture, with every effort being made to keep the moisture content of any one day's production below 6 pct. This goal was based on statistics of equipment available in the preparation plant, on some proposed minor alterations in the methods used for dewatering, and on the premise that plant output must be maintained.

The Methods Proposed for Reducing Moisture

The preparation plant dewatering set-up was studied and two methods for improving the results were given consideration. The first method involved spraying oil on the raw ¼x0-in. coal prior to water-wetting it ahead of the Deister tables. It was postulated that the oil spray would preferentially coat the coal particles and prevent them from being wetted by water. If the coal surfaces were not wetted, a centrifuge product having a lowered moisture content would be produced. This method was suggested by the experiences of the Lehigh Navigation Co. and the Semet-Solvay Co. The Lehigh Navigation Co. used a Bird centrifuge to dewater froth flotation products in an experimental plant. It was determined that the moisture content of the centrifuge cake varied considerably depending on the reagent used. The Semet-Solvay Co. experimented with Benzol and kerosene on a laboratory scale and with kerosene on a plant scale and determined that reagents of this type would lower the moisture content of a centrifuge cake.

The second method, based on Semet-Solvay experience, involved revamping of the interior design of the Bird centrifuges to allow introduction of relatively clear classifying water which would remove slimes not removed by the classification action that normally takes place in the large diameter end of the centrifuge bowl. Semet-Solvay experience indicated that the centrifuge cake moisture could be reduced by several per cent. This method, obviously, would provide better results in a plant using a positive pulp bleed than it would in one operated with an interior closed circuit. At Russellton, prior to the experimental program, approximately 600 gpm of a slimy pulp was removed from the circulating water system and thickened by means of a 75-ft diam Dorr thickener. The thickener underflow, at the rate of 200 gpm, was pumped to a waste pond at intervals aggregating approximately 20 pct of the total operating time. This underflow contained between 20 and 30 pct solids by weight and served to remove slime solids, thus preventing a buildup of slimes in the system. The thickener overflow ranged between 0.5 and 5.0 pct solids by weight.

The Base Comparison Period

For comparison purposes, the period between Aug. 1 and Sept. 26, 1951, was taken as a standard. The results of the experimental work would be evaluated in terms of similarities to or deviations from the base period. During this period the 3½x0-in. washed coal averaged 7.17 pct moisture, while the daily moistures fluctuated from 5.34 to 9.02 pct. The ¼x0-in. washed coal averaged 13.97 pct moisture, while the daily moistures fluctuated from 11.45 to 15.76 pct. The daily moisture values are tabulated in Table I and presented in graphic form in Fig. 1.

Results of Spraying Oil on Raw ¼x0 in. Coal

A light oil, Esso No. 45 Coalspray, was being used at Russellton at the rate of 0.1 gallon per ton of washed coal to improve the bulk density of the coke oven charge and to freezeproof the washed coal in transit. The existing spray line was extended into the plant, and the same oil, at the same flow rate, was sprayed on the raw ¼x0-in. coal as it discharged from the raw coal sizing screens. The existing flow rate represented approximately 0.3 gal per ton of raw ¼x0-in. coal. After being oiled, the coal went through two transfer points prior to entering the water-wetting box providing a mixing of oil and coal.

Preliminary results with the oil spray were encouraging, as can be seen by looking at Fig. 2. The moisture content of the washed coal was reduced and, in addition, the ash content of the table-washed coal went down while the ash content of the table refuse went up. A thin froth consisting of small bubbles was observed on the coal flow portion and discharge side of each table, and it seemed that a solution had been found.

The moisture reduction obtained did not meet the objectives, however, so the amount of oil added was doubled. The first result was an increase in washed coal moisture. Large and numerous bubbles flowed across the table. Bubbles began to form on the surface of the Chance cone and a heavy froth started to build up on the water surface of the Dorr thickener. When the froth on the thickener became several feet thick it was necessary to remove it by means of a power shovel. Then the froth began to plug pipelines in the plant and a soft spot developed in the rubber covering of one of the tables. Since all the conveyors in the plant were either flight or bucket-type, the oil did not harm them but instead served as a lubricant. The plugging of the pipelines, the building up of the heavy froth on the thickener, and the small decrease in moisture, combined, led to abandonment of the oil addition method.

Results Obtained by Using Classifying Water In the Bird Centrifuge

The Bird Machine Co. and the Semet-Solvay Co. had already obtained a moisture reduction of several per cent, as mentioned previously, in the Bird centrifuge dewatered fine coal produced at both the Harewood and Trailee plants of the Semet-Solvay Co. Republic Steel was given the benefit of this experience. Figs. 3 and 4 show the changes made in a standard Bird coal centrifuge to provide the desired classifying action. Fig. 3 shows the 2-in. classifying waterline carried inside the slurry feedline, the new discharge port in the slurry feedline, some of the new feed ports discharging to the spiral, a baffle placed across the cone to direct the classifying water, and the placement of one of the six classifying water nozzles. Fig. 4 shows how the original filtrate ports were altered to lower the pool depth and obtain a better classifying or desliming action.

William Noone, Preparation Engineer with Semet-Solvay Co., reported that it is essential that the classifying water be applied at the point where the

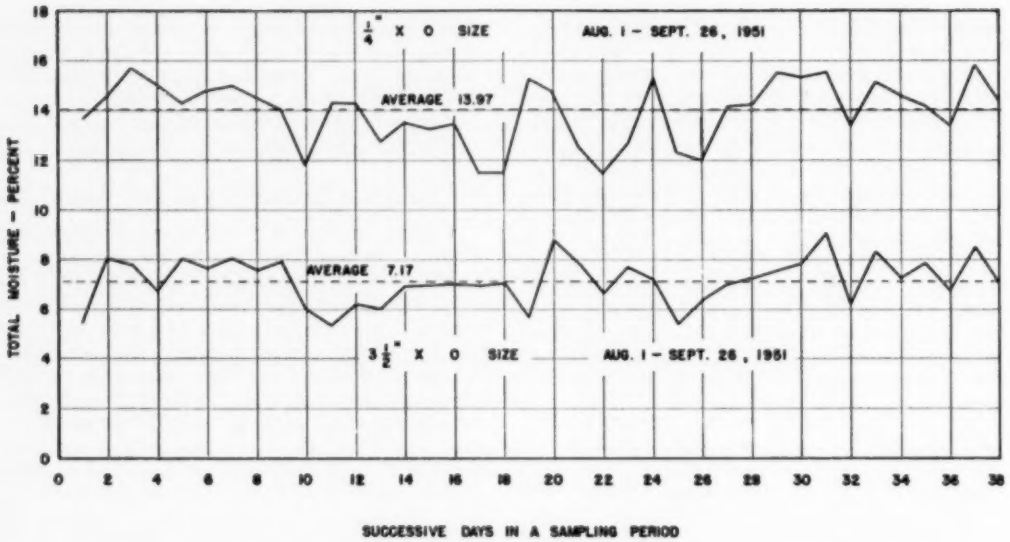
¼" X 0 SIZE
AUG. 1 – SEPT. 26, 1951
AVERAGE 13.97
AVERAGE 7.17
3½" X 0 SIZE
AUG. 1 – SEPT. 26, 1951
TOTAL MOISTURE – PERCENT
SUCCESSIVE DAYS IN A SAMPLING PERIOD

Fig. 1—A graphic presentation of daily moisture values shown in Table I. A base period from Aug. 1 to Sept. 26, 1951, was used as standard.

coal is changing direction as it moves forward under the impetus of the spiral. The change in slope in the centrifuge bowl provides a turning movement of each particle within the mass of the coal particles; therefore the classifying water should be added at or just prior to the change of slope point. Classifying water hitting a mass of coal moving as a constrained unit would have little desliming effect. The turning and rubbing of coal particle on coal particle helps to dislodge slime particles and definitely exposes more surface to water contact.

The normal method of operation at Russellton was and is to operate three Bird centrifuges on a continuous basis. A spare spiral is kept on hand which is used to replace the spiral in No. 1 centrifuge when its edges are worn down. No. 1 spiral is rebuilt and used to replace No. 2 spiral. Then No. 2 is rebuilt and used to replace No. 3 and so on. With this system of operation it was necessary to convert the centrifuges to the classifying water method on a one by one basis.

Fig. 5 presents in graphic form the moisture data contained in Table I for the period between Nov. 19 and Dec. 26, 1951. During this period No. 1 centrifuge was operated with classifying water, and No. 2 and 3 without it. The water addition represented approximately 70 gpm at 27-lb pressure. There was an immediate decrease in the moisture contents of both the 3½x0-in. and the ¼x0-in. washed coal products. The 3½x0-in. washed coal

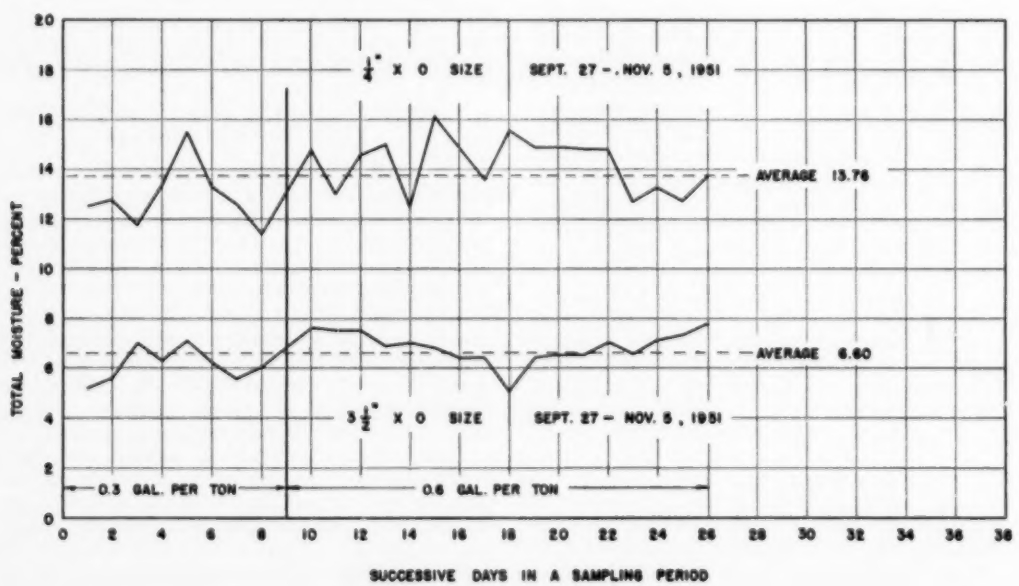
¼" X 0 SIZE
SEPT. 27 – NOV. 5, 1951
AVERAGE 13.76
AVERAGE 6.60
3½" X 0 SIZE
SEPT. 27 – NOV. 5, 1951
0.3 GAL. PER TON
0.6 GAL. PER TON
TOTAL MOISTURE – PERCENT
SUCCESSIVE DAYS IN A SAMPLING PERIOD

Fig. 2—Oil additive periods. Preliminary results were encouraging.

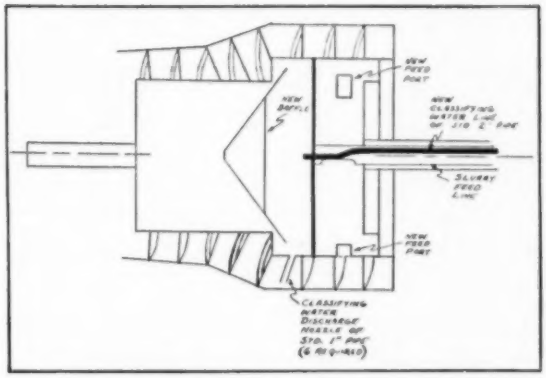
NEW FEED PORT
NEW BAFFLE
NEW CLASSIFYING WATER LINE OF 3/8" I.D. PIPE
SLURRY FEED LINE
NEW FEED PORT
CLASSIFYING WATER DISCHARGE NOZZLE OF STD. 1" PIPE

Fig. 3—Changes made in Bird centrifuge to allow introduction of classifying water for removing extra slimes.

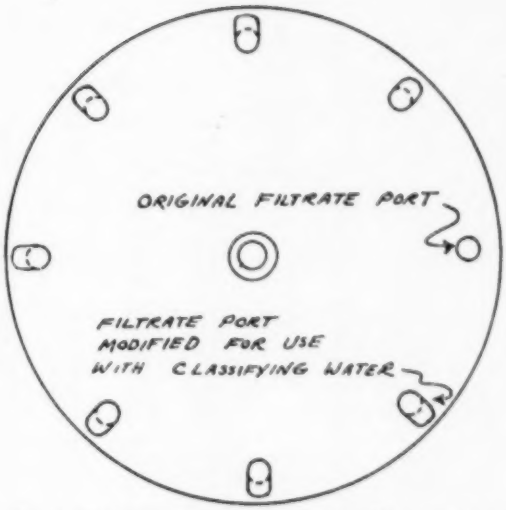

Fig. 4—Changes made in Bird centrifuge filtrate ports to allow use of classifying water.

averaged 6.54 pct moisture, with fluctuations between 4.49 and 7.84 pct, and the ¼x0-in. washed coal averaged 12.75 pct moisture, with fluctuations between 11.23 and 13.93 pct.

Fig. 6 presents in graphic form the moisture data contained in Table I for the period between Dec. 26, 1951, and Feb. 22, 1952. During this period No. 1 and 2 centrifuges were operated with classifying water additions and No. 3 was operated without classifying water. The water addition represented approximately 70 gpm per centrifuge. During this period the moisture contents of both the 3½x0-in. and the ¼x0-in. washed coal products decreased. The 3½x0-in. washed coal averaged 5.78 pct moisture, with fluctuations between 4.74 and 7.28 pct, and the ¼x0-in. washed coal averaged 11.48 pct moisture, with fluctuations between 10.49 and 12.88 pct.

Fig. 7 presents in graphic form the moisture data contained in Table I for the period between Feb. 23 and March 31, 1952. During this period all three centrifuges were operated with classifying water, supplied at the rate of approximately 70 gpm per centrifuge. During this period the 3½x0-in. washed coal showed a slight decrease in moisture while the ¼x0-in. washed coal contained the same average moisture as in the previous period. The 3½x0-in. washed coal averaged 5.60 pct moisture, with fluctuations between 4.49 and 6.90 pct, and the ¼x0-in. washed coal averaged 11.48 pct moisture, with fluctuations between 10.31 and 12.66 pct.

Fig. 8 presents in graphic form a summary of the moisture reduction results obtained at Russellton. The 3½x0-in. washed coal moisture went from an average of 7.17 pct at the start of the testing period down to an average of 5.60 pct at the end of the period. The ¼x0-in. coal moisture went from an average 13.97 pct at the start of the testing period to an average 11.48 pct at the end of the period.

The Effect of Size-Consist on Moisture Content

Fig. 8 also presents in graphic form a summary of the percentages of −¼x0-in. washed coal in the combined 3½x0-in. washed coal during the major portion of the testing program. The amount of −¼ in. showed a marked decrease between the second and third testing periods, i.e., the oil additive and one centrifuge equipped with classifying water periods, and a marked increase between the third and

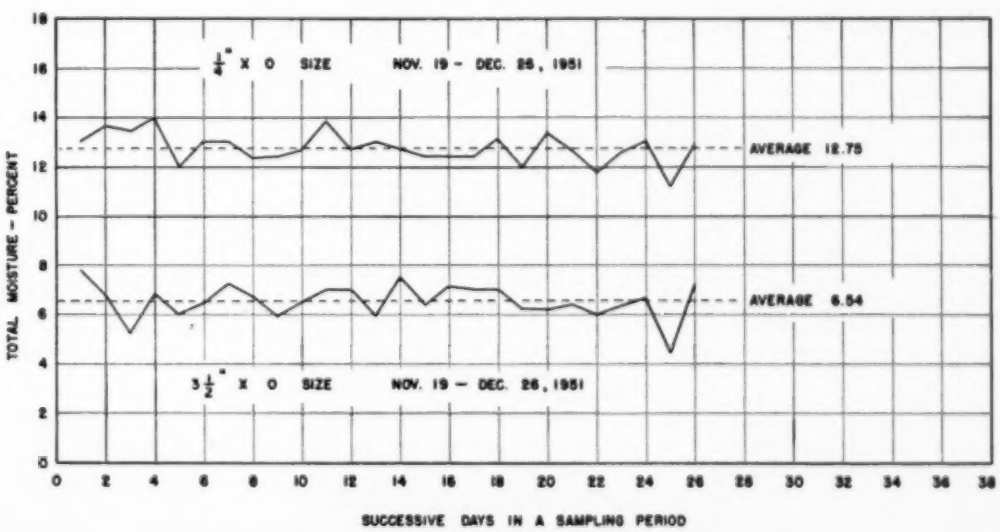
¼" X 0 SIZE NOV. 19 – DEC. 26, 1951
AVERAGE 12.75
AVERAGE 6.54
3½" X 0 SIZE NOV. 19 – DEC. 26, 1951
TOTAL MOISTURE – PERCENT
SUCCESSIVE DAYS IN A SAMPLING PERIOD

Fig. 5—Period during which classifying water was added to No. 1 centrifuge only.

Table I. A Tabulation of Moisture and Size Consist Values

Sample No.	Base Period			Oil Add Period			No. 1 Centrifuge Back Washed			No. 1 and 2 Centrifuges Back Washed			No. 1, 2 and 3 Centrifuges Back Washed		
	¼xO-In., H_2O, Pct	3½xO-In., H_2O, Pct	¼xO-In., W.C. Wt., Pct	¼xO-In., H_2O, Pct	3½xO-In., H_2O, Pct	¼xO-In., W.C. Wt., Pct	¼xO-In., H_2O, Pct	3½xO-In., H_2O, Pct	¼xO-In., W.C. Wt., Pct	¼xO-In., H_2O, Pct	3½xO-In., H_2O, Pct	¼xO-In., W.C. Wt., Pct	¼xO-In., H_2O, Pct	3½xO-In., W.C. Wt., Pct	¼xO-In., W.C. Wt., Pct
1	13.62	5.46		12.51	5.23		13.07	7.84	30.95	12.60			10.98	5.35	26.82
2	14.51	7.96		12.73	5.62		13.67	6.79	34.15	10.63			10.97	6.90	
3	15.60	7.75		11.81	6.90		13.52	5.18	26.48	12.25	6.75		11.83	5.00	30.02
4	15.11	6.75		13.41	6.34		13.93	6.77	29.63	11.61	6.09		10.90	6.03	31.87
5	14.28	8.02		15.44	7.03		12.03	6.07	32.13	12.78	6.30		11.10	5.13	34.90
6	14.72	7.62		13.31	6.12		13.02	6.44	33.05	12.88	6.78		11.42	4.90	28.35
7	14.98	8.04		12.62	5.63		13.02	7.20	33.05	11.51	6.25		12.28	5.17	30.17
8	14.52	7.56		11.35	6.01		12.32	6.74	30.00	10.50	6.53		11.72	5.02	29.43
9	14.08	7.87		12.96	6.70	32.75	12.42	5.97	28.90	11.12	5.77		11.49	5.44	31.68
10	11.77	6.60		14.73	7.62	33.63	12.61	6.51	30.56	11.25	7.28		11.25	5.13	30.80
11	14.33	5.34		13.01	7.54		13.80	6.95	30.70	10.59	4.74		11.17	4.49	34.50
12	14.17	6.13		14.55	7.52	31.94	12.76	6.97	23.20	10.49	5.65		11.73	6.64	29.15
13	12.74	5.99		14.96	6.88	32.80	12.99	6.00		11.79	5.30		11.08	6.37	34.98
14	13.51	6.83		12.52	7.06	34.35	12.68	7.39	32.00	11.64	6.04	37.25	11.10	5.91	35.40
15	13.23	6.90		16.07	6.77	32.83	12.43	6.46	32.10	11.21	6.24	32.33	11.55	5.78	33.50
16	13.46	6.95		14.83	6.39	30.83	12.43	7.13	28.10	11.33	5.82	27.28	11.49	4.94	36.50
17	11.57	6.89		13.65	6.37	30.43	12.41	6.93	26.35	12.22	6.23	35.55	11.18	5.57	34.60
18	11.45	6.99		15.48	5.14	29.35	13.09	7.05	27.63	11.08	6.04	27.03	12.50	6.56	27.50
19	15.25	5.70		14.93	6.34	32.65	12.01	6.20	21.90	12.18	5.17	27.58	12.66	6.26	29.45
20	14.74	6.70		14.93	6.48	32.23	13.37	6.18	28.33	12.17	6.67	26.93	11.85	6.15	29.20
21	12.52	7.83		14.77	6.53	34.78	12.66	6.36		11.67	6.92	32.28	11.78	5.72	29.78
22		8.07		14.82	7.04	31.95	11.74	6.09	31.65	11.76	5.20	31.78	12.31	6.02	29.97
23	11.59	6.63		13.25	7.14	30.25	12.51	6.32	22.80	11.97	5.64	32.70	11.23	4.73	29.33
24	13.67	7.62		12.69	6.62	34.70	12.98	6.65	26.75	11.45	5.73	31.63	11.20	5.55	31.50
25	15.34	7.15		12.69	7.30	33.20	11.23	4.49	29.50	11.17	6.35	30.92	10.31	5.28	29.58
26	12.26	5.37					12.86	7.22	23.90	11.67	6.24		11.35	5.47	28.95
27	12.09	6.34								11.15	6.06	30.28			
28	14.07	6.90								11.82	5.56	31.73			
29	14.18	7.23								11.29	5.36	30.53			
30	15.47	7.53								11.78	5.51	28.88			
31	15.43	7.80								11.99	6.00	31.57			
32	15.58	9.02								10.78	5.69	27.45			
33	13.62	6.23								11.25	5.38	32.38			
34	15.16	8.25								11.16	5.20	33.60			
35	14.68	7.18								10.92	4.98	32.78			
36	14.19	7.86								10.64	4.71	28.22			
37	13.43	6.77								10.66	6.07	31.18			
38	15.76	8.51								11.70		31.95			
39	14.29	6.94								11.14	5.01	29.73			
40											5.83	30.10			
41										11.17	5.97	26.02			
42										11.90	5.71	32.05			
Average	13.97	7.17		13.76	6.60	32.42	12.75	6.54	28.91	11.48	5.78	31.11	11.48	5.60	31.12

fourth testing periods. Periods 2, 4, and 5 showed little variation, however, and it seems safe to assume that the size-consist of the washed coal had little to do with moisture reduction obtained.

The addition of approximately 210 gpm of classifying water to the centrifuges did not add materially to the amount of circulating water in the system. In effect, about 30 gpm of additional fresh water was required. Some clear makeup water was diverted from other addition points and the remainder of the classifying water was made up of clarified water overflowing the 75-ft diam Dorr thickener. Periodic samples of the thickener overflow showed an increase in its solid content, and to keep the overflow solids content in the range of 5 to 10 by weight it was necessary to operate the thickener underflow

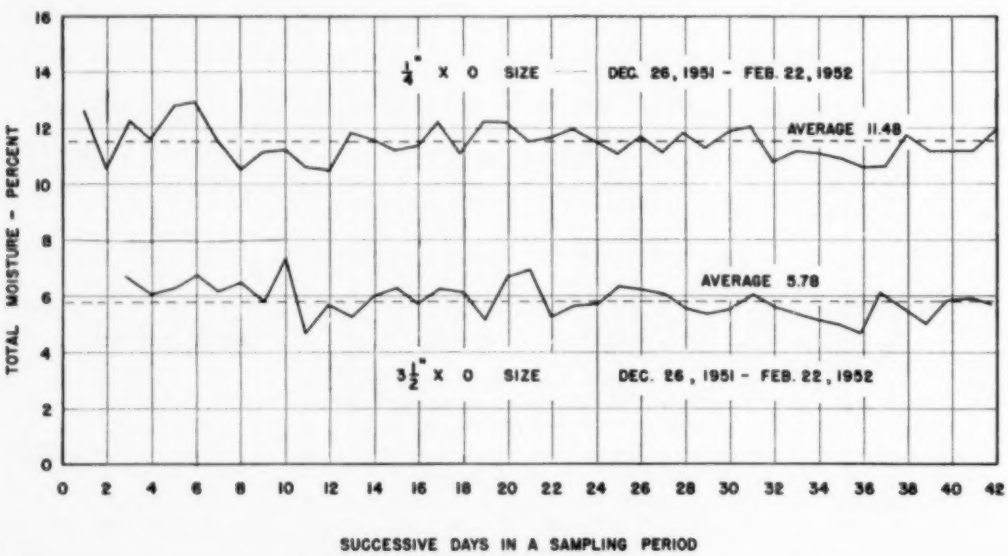
¼" X 0 SIZE — DEC. 26, 1951 - FEB. 22, 1952
AVERAGE 11.48
AVERAGE 5.78
3½" X 0 SIZE DEC. 26, 1951 - FEB. 22, 1952
TOTAL MOISTURE - PERCENT
SUCCESSIVE DAYS IN A SAMPLING PERIOD
0 2 4 6 8 10 12 14 16
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42

Fig. 6—Period during which classifying water was added to No. 1 and No. 2 centrifuges.

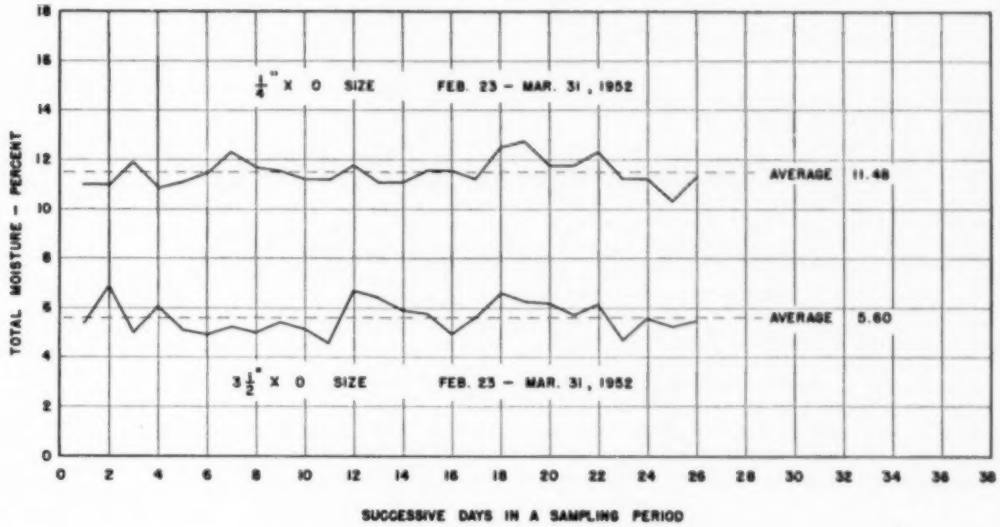
¼" X 0 SIZE FEB. 23 – MAR. 31, 1952
AVERAGE 11.48
AVERAGE 5.60
3½" X 0 SIZE FEB. 23 – MAR. 31, 1952
TOTAL MOISTURE – PERCENT
SUCCESSIVE DAYS IN A SAMPLING PERIOD

Fig. 7—Period during which classifying water was added to all three centrifuges.

pump approximately 35 pct of operating time, in place of the 20 pct previously reported.

Effect of Classifying Water on Centrifuge Wear

The use of classifying water in the centrifuges increased the rate at which the edges of the spirals wore and also increased wear on other portions of the machine. Prior to use of the classifying water a centrifuge would handle approximately 60,000 tons of ¼x0-in. coal before it would have to be overhauled. After the use of classifying water was started a centrifuge would handle only 30,000 tons of ¼x0-in. coal before it had to be overhauled. The use of ½-in. high retaining strips on the inside of the drum allowed a build-up of coal particles, saved wear on the drum, and increased the wear-life between overhauls to approximately 45,000 tons.

The Semet-Solvay Co. encountered more or less the same wear difficulties and working with representatives of the Bird Machine Co. found that changing the centrifuge speed from 640 rpm to approximately 540 rpm prolonged spiral life and still allowed production of a low moisture content centrifuge cake. It is the intention at Russellton to try the reduced centrifuge speed as soon as possible.

The ash content of the centrifuge cake produced during the base period of Aug. 1 through Sept. 26, 1951, averaged 8.60 pct. The variation in ash content was from 8.00 pct to 9.51 pct. The ash content of the centrifuge cake produced during the final classifying period of Feb. 23 through March 31, 1952, averaged 8.06 pct. The variation in ash content was 7.45 pct to 8.90 pct. It seems obvious that the material being removed by the classifying water was a high-ash slime.

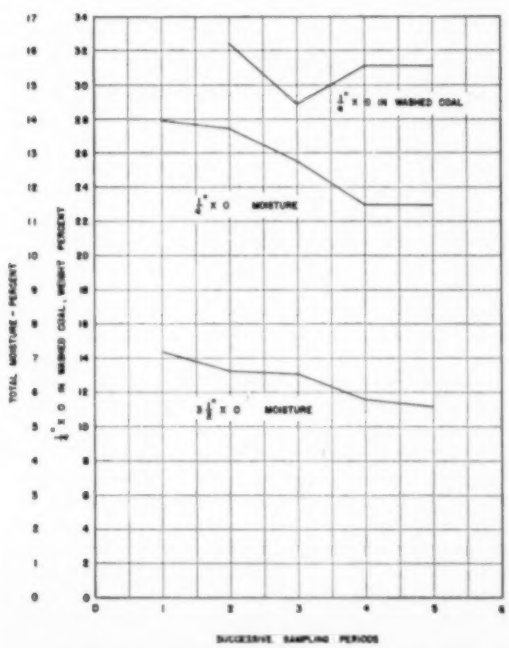
¼" X 0 IN WASHED COAL
¼" X 0 MOISTURE
3½" X 0 MOISTURE
TOTAL MOISTURE – PERCENT
¼" X 0 IN WASHED COAL, WEIGHT PERCENT
SUCCESSIVE SAMPLING PERIODS

Fig. 8—Summary of moisture results at Russellton.

Conclusions

The addition of small amounts of a light oil to ¼x0-in. raw Thick-Freeport coal, prior to treatment by means of wet tabling, will not materially reduce the moisture content of the cake produced by a Bird centrifuge. Oil additions were beneficial from an ash reduction standpoint but created so many operating difficulties that the additions had to be abandoned.

The use of classifying water to remove slimes not removed by normal centrifuge classification provided a marked reduction in the moisture content of the cake produced by a Bird centrifuge. The ¼x0-in. washed coal moisture averaged 13.97 pct prior to the use of classifying water and 11.48 pct after the use of classifying water. This is a reduction of 2.49 pct. The 2.49 pct reduction in fine coal moisture helped to reduce the moisture content of the composite 3½x0-in. washed coal by 1.57 pct.

The use of classifying water also reduced the ash content of the cake produced by a Bird centrifuge. The objectives of the moisture reduction program were attained. The one disadvantage was that centrifuge maintenance requirements were increased.

Providing Large Industrial Water Supplies by Induced Filtration

Water supplies dependent upon induced infiltration can be developed by vertical wells, by infiltration galleries, or by horizontal water collectors. Each method is described and the advantages of water obtained by induced infiltration with respect to cost, chemical quality, and temperature are shown by specific water supplies.

by Fred H. Klaer, Jr.

THE subject of ground water in industry is assuming increasing importance as new processes and new industries are developed. Industrial specifications of chemical quality and temperature for process water and for cooling purposes are becoming more rigid, and water must now have many properties to meet these requirements. As ground water is usually more constant in quality and temperature, many industries are turning to ground-water supplies to satisfy their growing need.

As many published articles have stated during the past several years, the ever increasing demands have caused shortages of water supply in many localities throughout the United States. Although such shortages are generally of a local nature, they have given rise to many attendant problems, such as increased pumping costs, salt water encroachment, and rising ground-water temperatures.

One partial solution to the problems of overdevelopment of the ground-water reservoirs in many areas can be accomplished by developing ground-water supplies that are dependent upon induced infiltration and by planning the use of underground reservoirs. These reservoirs can be filled during periods of excess precipitation and stream flow and can be emptied during periods of drought, in a manner similar to the use of surface reservoirs. In this way water that otherwise would be wasted into the oceans is salvaged during periods of excess.

The development of water supplies dependent on induced infiltration is a relatively new concept and should be defined. When a well is pumped, the water level around the well is lowered in the shape of an inverted cone or *cone of depression*. As pumping is continued, the cone of depression will continue to expand, horizontally and vertically, until the quantity of water crossing the perimeter of the cone plus the recharge within the area of the cone is equal to the quantity of water being pumped.

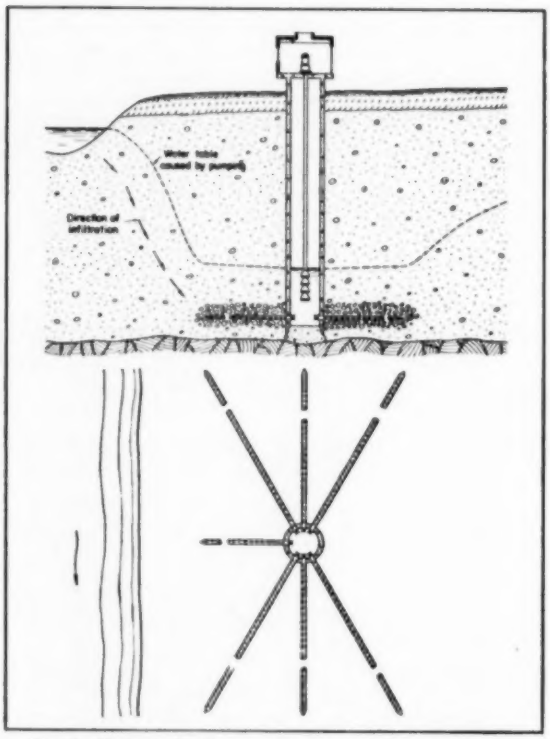

Fig. 1—Horizontal collector designed to induce infiltration.

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Discussion on this paper, TP 3525H, may be sent (2 copies) to AIME before Aug. 31, 1953. Manuscript, Oct. 30, 1952. Chicago Meeting, September 1952.

Along most of the larger rivers of the United States and particularly in the northeastern quarter of the country that has been subjected to continental glaciation, alluvial deposits of sand and gravel have been left during glacial and post-glacial times. The materials are gravels, sands, silts, and clays in mixtures of various proportions. These deposits are generally sorted and stratified.

Under natural conditions water falling as precipitation on the earth's surface saturates the surficial materials and moves in a general horizontal direction to drain into some surface stream. If, however, a well, infiltration gallery, or water collector located in the alluvial deposits of sand and gravel adjacent to the stream is pumped, the cone of depression developed by pumping the well will change the hydraulic gradient toward the stream and water will move from the stream toward the well and into the aquifer. This process is called *induced recharge* or *induced infiltration*.

The process of induced infiltration assures the permanency of the water supply, as it derives water from a perennial source and is not dependent on recharge caused by the seasonal distribution of rainfall and the growing season. Even in cases where the surface source of water may become deficient during the dry summer months, water supplies dependent on induced infiltration may be maintained if sufficient ground-water storage is available to produce the required quantities of water during the period of deficient stream flow. Ground-water levels may be lowered and the available ground-water storage deliberately decreased during dry periods, as long as sufficient excess flow is available during the remainder of the year to replenish the storage. The utilization of ground-water aquifers as underground reservoirs, controlled in a manner similar to the control of surface reservoirs, will become an industrial necessity in certain areas as the demands for ground water surpass the natural rates of recharge.

The principles and theory of induced infiltration have been discussed in detail by Meinzer,[1] Kazmann,[2, 3] Rorabaugh,[4, 5] and others, and only a brief discussion is required here. The requisite local conditions for inducing infiltration include a surface source of water such as a stream or lake that is connected hydraulically with an aquifer. The aquifer may be a consolidated formation but is usually a deposit of permeable sand and gravel open to the stream so that water may flow in either direction between the surface source and the aquifer.

When a well is pumped, the shape of the developed cone of depression in the vicinity is controlled largely by the permeability of the formation, the quantity of water being pumped, and the total available head. Under homogeneous conditions the cone of depression is circular in shape and symmetrical around the well. Ground water flows toward the well equally from all directions if the permeabilities of the aquifer, the hydraulic gradients, and the areas through which the water passes are uniform.

If, however, a well is placed near a perennial stream that is interconnected hydraulically with the aquifer, the cone of depression will become distorted with the steeper slopes toward the stream, and water will flow from the stream into the aquifer to replace that which has been pumped out. Since sufficient recharge is available from the perennial stream, the cone of depression toward the stream will eventually assume a relatively stable shape. The ultimate quantity of water that can be obtained can be determined in advance by a detailed hydrogeological survey.

Methods of Developing Water Supplies By Induced Infiltration

The principal methods of developing water supplies by induced infiltration are those normally used in the collection of ground water, namely, vertical wells, infiltration galleries, and horizontal water collectors. For each method there are advantages and disadvantages as to initial cost, efficiency yield, operation, and longevity.

Vertical wells have been used successfully for many years, especially along the larger streams in the United States such as the Ohio River in Pennsylvania[6] and West Virginia.[7, 8] The relative cost of a vertical well system to induce infiltration is often lower than other methods, but such a system has certain inherent disadvantages from the standpoint of efficiency, maintenance, operation, and longevity.

The cone of depression developed by all wells is made up of a head loss due to the movement of water through the aquifer to the well plus an additional loss in head required to move the water through the screen and to the pump intake. This latter so-called *well loss* factor is believed to be due in part to the change from laminar to turbulent flow in the immediate vicinity of the well. In some wells, the well loss factor may constitute more than half the total drawdown. In formations of limited thickness such as the alluvial and glacial terrace deposits along many of the streams of the United States, a system of vertical wells can develop only a fraction

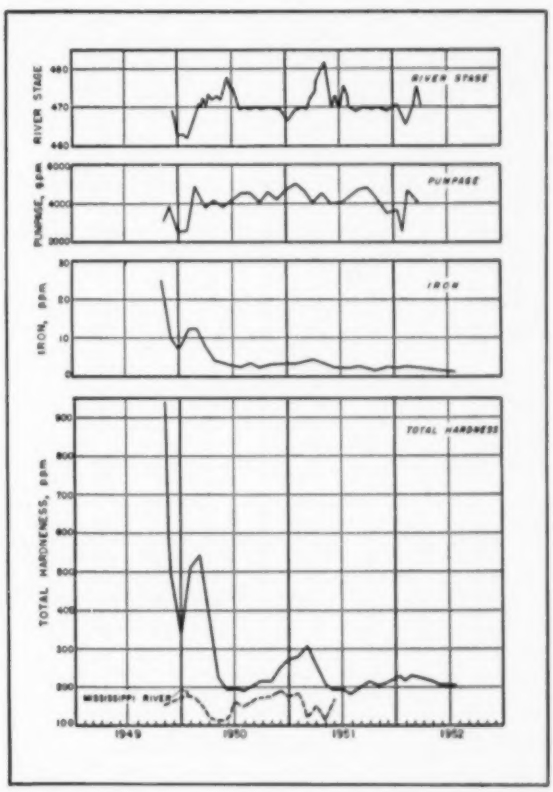

Fig. 2—River stage, pumpage, iron content, and total hardness of water from horizontal collector at Central Fiber Products Co., Quincy, Ill.

of the total head available in the aquifer. Under uniform conditions of permeability and thickness the cone of depression developed by a vertical well is roughly circular. Although some distortion of the cone is caused by induced infiltration, the actual quantity of water that can be developed by a vertical well is limited.

The oldest method of inducing recharge is probably the infiltration gallery, which has been in use since the days of early Greece. The most famous infiltration gallery in this country is probably that used by Des Moines, Iowa.[9] Infiltration galleries usually intercept more water than wells, especially in shallow aquifers, and cost less to operate and maintain, but they are considerably more expensive to construct.[10] From a practical economic standpoint the depth to which infiltration galleries can be constructed is limited. They may consist of tunnels, walled conduits with many openings, or a pipeline with open joints or openings in the pipe similar to the many types of strainers used in filter or in vertical wells. They are constructed in unconsolidated materials below the water table and seldom exceed 20 ft in depth. They may be constructed either parallel or normal to the source of recharge.

A relatively new device for obtaining large supplies of water by induced infiltration is the horizontal water collector, see Fig. 1. A large reinforced concrete caisson is sunk to the bottom of unconsolidated deposits of sand and gravel adjacent to a stream. The bottom of the caisson is then plugged and through ports near the base of the caisson horizontal screens are projected to distances of several hundred feet into the aquifer, similar to the spokes of a wheel. The screens are projected by a combination washing and jacking process, a large part of the finer material being removed and a natural gravel wall being developed in place around each horizontal screen.

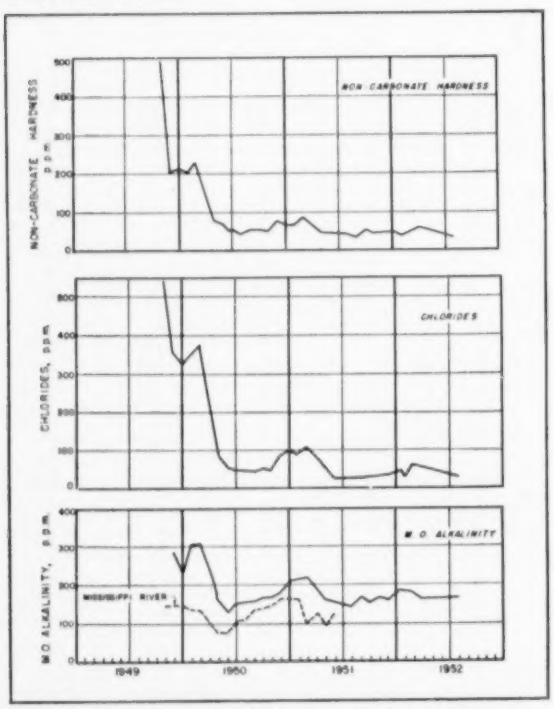

Fig. 3—Non-carbonate hardness, chloride content, and M. O. alkalinity of water from horizontal collector at Central Fiber Products Co., Quincy, Ill.

A horizontal collector is in reality a special type of infiltration gallery in that the pattern of projecting the horizontal screens can be controlled to develop a long section of aquifer parallel to the source of induced infiltration. The horizontal collector can be constructed economically to much greater depths than the average infiltration gallery, thereby utilizing the full available head in the aquifer. Because of the large amount of screen that can be projected, as much as 2000 ft of pipe in some collectors, the entrance velocity of water entering the screens is extremely low, thereby minimizing sudden changes in pressure and well loss and eliminating encrustation. The yields of individual collectors may exceed 20 million gal of water per day under favorable hydrogeological conditions.

There are at the present time more than 100 horizontal collectors in operation or under construction in the United States and about 20 in Europe. The yields of the individual unit range from less than 1 to more than 20 million gal per day. The life of a horizontal collector is as yet unknown, although several units have been in operation for 10 to 15 years without loss of capacity.

Industrial Advantages of Water Supplies Dependent on Induced Infiltration

In the planning of an industrial water supply, several factors must be considered. The ultimate aim in such planning is to obtain a permanent dependable supply of suitable quantity and quality at the lowest unit cost, including not only initial capital cost but also costs of operation and maintenance. The capital cost of a given type of water supply is generally considerably less during the full life of the installation than the costs of operation and maintenance.

Water supplies dependent upon induced infiltration are permanent in that the quantity available to infiltration is usually in excess of the quantities of water required. It is true that the flow of surface streams may vary within wide limits, but it is possible to estimate within close limits the quantity of water that will be available during any given year. The records of stream flow in the United States, collected by the U. S. Geological Survey, the U. S. Corps of Engineers, the U. S. Weather Bureau and many state agencies, generally provide an adequate estimate of the quantity of water that will be available over a period of years. Since infiltration can be induced into underground reservoirs during periods of excess stream flow, these same reservoirs can be drawn on during periods of deficient stream flow to provide from storage the required quantities of water.

The unconsolidated deposits of sand and gravel along many streams may be considered as large natural filters, comparable in many ways to very large slow sand filters. The water obtained by induced infiltration, having been filtered naturally through filters far larger and thicker than any made by man, and at much slower rates of flow, will be free from all turbidity or colloidal and suspended solid matter. The rates of filtration and the velocity of movement through the natural filters are extremely slow and removal of all solids is complete.

Experience, especially in the use of horizontal water collectors, has shown that all organic matter and pathogenic bacteria are removed from water by induced infiltration. Although the removal is not

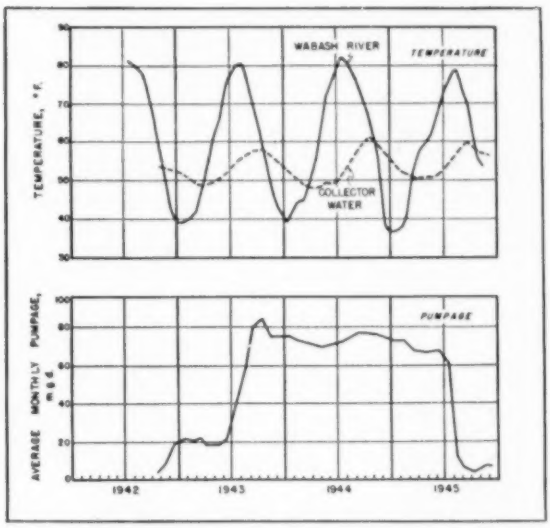

Fig. 4—Temperature of Wabash River and of water and pumpage from horizontal collectors at Wabash River Ordnance Works, Clinton, Ind.

yet fully understood, it is believed that this is accomplished by a thin *filter scum* layer that forms on the stream bottom and that the removal is accomplished in part by oxidation and in part by bacterial action. In recent experiments in California on sewage reclamation by spreading basin infiltration Stone and Garber[11] have found that under aerobic conditions of excess oxygen almost complete destruction of organic matter was accomplished after only 7 ft of filtration. These experiments, although not conclusive with regard to induced infiltration from streams, suggest that the major factor in the destruction of organic matter is probably oxidation. This destruction is sufficiently effective to remove even phenols from water pumped from horizontal collector installations along the Ohio River.[2, 10]

Throughout a large part of the industrial area of the United States the ground water is generally more mineralized than the water in the surface streams, being higher in total hardness, iron, sulphate, chloride, and alkalinity. Water obtained by induced infiltration is a mixture of normal ground water and surface water, and in many localities the chemical quality of induced infiltration water will approach the average chemical quality of the surface stream. Records of chemical quality of water from a horizontal collector of the Central Fibre Products Co. at Quincy, Ill., over a period of more than two years show the changes in chemical quality that may occur, see Fig. 2. The collector, located on the east bank of the Mississippi River, is about 80 ft deep, and the horizontal screens are projected approximately 50 ft below low river level. The collector has a design capacity of 7.5 million gal per day, although the actual pumpage has averaged about 6.8 million gal per day. The original water pumped, which was normal ground water, contained 945 ppm total hardness, 1010 ppm chlorides, 450 ppm alkalinity, and 25 ppm iron. Pumping of the collector was started in November 1949, and the quality of the water improved markedly during the first few months. By June 1950 the iron had dropped to 3 ppm, the total hardness to 200 ppm, the non-carbonate hardness from about 500 to 50 ppm, the chlorides to 50 ppm, and the alkalinity from about 290 to 150 ppm, Figs. 2 and 3. It is apparent from the trend in changes that the ultimate quality of the collector water will approximate the average quality of the river water.

The importance of temperature and humidity control to many industries needs little comment, and the use of water as a cooling medium is becoming increasingly important. Since the temperature of normal ground water is relatively constant and considerably lower than the temperature of air or surface water during the hot summer months, ground water is usually preferred for industrial cooling purposes when available. The temperature of water obtained by induced infiltration will fluctuate in a manner similar to the fluctuation of temperature of the stream source. However, the range in fluctuation will be considerably smaller and the maximum temperature of induced infiltration water will lag the maximum temperature of the surface stream by as much as three months. At the Wabash River Ordnance Works, Clinton, Ind., where a system of six horizontal collectors produced more than 80 million gal of water per day, see Fig. 4, the temperature of the Wabash River fluctuated generally between 37° and 82°F. The temperature of the collector water, however, ranged between 47° and 61°F, even though the collectors were located relatively close to the river. The maximum temperatures of collector water occurred generally about 1½ months after the maximum temperatures of the Wabash River.

Rorabaugh in a recent paper on stream bed percolation in water-supply development[6] presents data on the operation of a horizontal water collector at the National Carbide Co. at Louisville, Ky. The information he presents on the temperature of the water produced is of especial interest and will be discussed briefly, see Fig. 5. The collector, located on the east edge of the Ohio River, extends about 40 ft below pool stage of the river and about 72 ft above pool stage, so that the pump floor is above flood level. The collector was designed to produce 3.5 million gal a day but has been pumped at a somewhat smaller rate during the past few years. Thermocouples were installed in at least three lateral screens and records were kept of the temperature of the water from the Ohio River, the water from the collector, and the water discharged from individual laterals extending toward the river, upstream parallel to the river, and away from the river. These data are summarized in Table I.

This shows conclusively that the aquifer is an effective heat-exchange unit and that its effective-

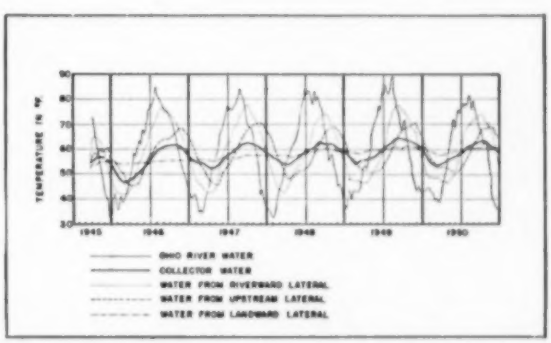

Fig. 5—Temperature of Ohio River and of water from various horizontal lateral screens in horizontal collector at National Carbide Co., Louisville, Ky. Compiled by M. I. Rorabaugh, U. S. Geological Survey.

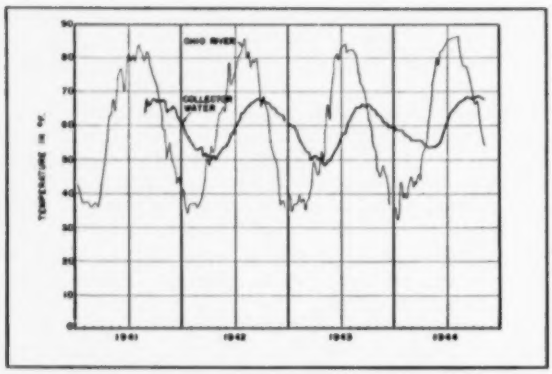

Fig. 6—Temperature of Ohio River and water from horizontal collectors at Indiana Ordnance Works, Charlestown, Ind.

ness can be increased if the distance to the effective line of infiltration is increased. This allows the industrial user to design his water supply to suit his particular requirements.

Similar data for a horizontal collector system at the Indiana Ordnance Works at Charlestown, Ind., have been presented by Kazmann.[8] This development consisted of seven horizontal water collectors spaced along the north bank of the Ohio River at intervals of 1300 to 2000 ft. The design capacity of the complete system was about 70 million gal of water a day. The system however was pumped at rates of 28 to 56 million gal per day. Although the temperature of the Ohio River ranged between 86°

Table I. Comparison of Water Temperatures

Source of Water	Maximum Temperature, °F	Minimum Temperature, °F	Approximate Lag in Months
Ohio River	89	33	
Riverward lateral	78	42	1
Upstream lateral	70	45	4
Landward lateral	61	55	
Combined discharge of collector	65	47	2-3

and 33°F during the four-year period 1941 to 1944, see Fig. 6, the temperature of the water discharged from the collectors into the storage reservoir ranged from about 69° to 48°F. The maximum temperatures reached by the collector water occurred generally about 2½ months after the maximum temperatures of the Ohio River. Many similar differences have been noted in other installations.

It should be pointed out that infiltration into the ground-water reservoirs cannot be induced in all localities, as in many areas the geologic and hydrologic conditions are not suitable. A detailed hydrogeological survey will determine prior to construction whether infiltration can be induced and what the capacities of the collecting system will be.

Acknowledgments

The writer wishes to express his appreciation to Henry B. Weiss, Plant Manager, Central Fibre Products Co., Quincy, Ill., and to J. Carl Bode, President, National Carbide Co., New York, for permission to present operational data from horizontal collectors at their Quincy, Ill., and Louisville, Ky., plants, respectively. He also wishes to acknowledge the careful work of M. I. Rorabaugh, U. S. Geological Survey, Louisville, Ky., in compiling data from the National Carbide Co., Louisville, and the work of R. G. Kazmann, Consulting Engineer, Stuttgart, Ark., in compiling data from the Central Fibre Products Co., Quincy, Ill., the Wabash River Ordnance Works, Clinton, Ind., and the Indiana Ordnance Works, Charlestown, Ind.

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Correction

In the December 1951 issue: TP 3194B. Basic Laboratory Studies in the Unit Operation of Crushing, by J. W. Axelson, J. T. Adams, Jr., J. F. Johnson, J. N. S. Kwong, and E. L. Piret. P. 1068, col. 2, par. 2 should read: Rittinger's law is probably too simple a concept to encompass a complicated phenomenon and may very well not be a particularly desirable base or starting point for the development of a full understanding of crushing.

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aime NEWS

Members Receive Nova Scotia Material

Joint meeting plans for the Industrial Minerals Div., with the Canadian Institute of Mining and Metallurgy, and the Mining Society of Nova Scotia, are proceeding on schedule.

Registration cards have been mailed out to Industrial Mineral Div. members, along with tourist matter from the Nova Scotia Bureau of Information. A temporary shortage of tourist material developed and those not receiving any should write to the Nova Scotia Bureau of Information, Provincial Building, Halifax, Nova Scotia.

Columbia Section Meets

A program organized and presented by students of the University of Idaho and Washington State College, drew miners, geologists, and metallurgists to Pullman, Wash. Dwight L. Myers, Chairman of the Spokane Section made a brief introduction and Deans Spielman and Fahrenwald gave an explanation of the program.

Before the meeting, the metallurgical and mining facilities for teaching and experimental station were visited.

Conrad Pilz, president of the Washington State College AIME Chapter, and Robert Lathrop, president of the Idaho AIME Chapter, introduced the various speakers.

The Present Lead and Zinc Situation was discussed by William Grave; *Aluminized Iron*, J. R. Miller; and *Factorial Design vs Standard Testing* was the subject of Elwood Gray's talk. Cole McFarland explained the *Sluice Plate Operation in Alaska Gold Placers*. Bruce Wormald spoke on *Idaho Batholith; Spectroscopic Analysis as Applied to a Few Metallurgical Products* was discussed by Elwood Strom; and Clayton Harmsworth presented his subject, *Millisecond Delay Blasting*.

Among those active in the organization of the meeting was Whit Smith.

President Fletcher Visits Australia

Andrew Fletcher, left, presented the AIME Legion of Honor Medal to W. E. Wainwright, right, Honorary Treasurer of the Australasian Institute of Mining and Metallurgy, at the luncheon given by the Council of the AIMM. Looking on is M. A. Mawby, President of AIMM. Mr. Fletcher visited Australia in connection with the Fifth Empire Mining and Metallurgical Congress. Prior to his departure, he was presented with a certificate of Honorary Membership in the Australasian Institute.

AIME President Ends Six Weeks' Tour

President Fletcher returned to New York on May 6 after a six weeks' trip most of which was spent in Australia. He attended the Fifth Empire Mining and Metallurgical Congress in that country and gave several talks. Before leaving the country he was made an Honorary Member of the Australasian Institute of Mining and Metallurgy. On his return to the USA, Mr. Fletcher attended AIME meetings in San Francisco, Reno, Salt Lake City, Denver, Golden, and Casper. Within a week after his return he departed for Tulsa to attend a meeting of the Mid-Continent Section, AIME, and of the Board of Directors. After a tour of the International Petroleum Exposition, he stopped for a meeting of the Tri-State Section at Joplin, addressed the students at Rolla, attended a meeting of the St. Louis Section, and was honor guest of the Chicago Section on President's Night, May 23.

Clay Mineral Conference

Theme of the Clay Minerals Conference to be held at the University of Missouri, Columbia, Mo., Oct. 15 to 17, 1953 will be Genesis of Clays and Related Minerals.

Sponsoring the conference is the National clay Minerals Committee of the National Research Council. Those interested in presenting papers on Clay mineralogy, technology, physical behavior of clay, techniques of mineral determination, origin of soils, clays in soils, clays related to ore deposits, and allied topics can contact A. F. Frederickson, Washington University, St. Louis, Mo.

Outline Plans For Hibbing Fall Meeting

The Minerals Beneficiation Subsection of the Minnesota Section, AIME will be hosts for the Fall Meeting of the Minerals Beneficiation Div., August 31 to September 2, at Hibbing, Minn.

Plans haven't been finalized but a general outline of the meeting is complete. Meeting registration closes 11 am, August 31, with an orientation session covering geology, mining and field trips first on the list of events. A general luncheon will follow. A field trip is slated for the remainder of the first day.

September 1 and 2 is scheduled for field trips, with a full half day of technical papers sandwiched in. Papers will cover the following subjects:

1. Chemical and Mineral Properties of Taconites.
2. Application of Cyclones for Concentration of Ores.
3. Roasting of Iron Ores.
4. Sintering and Nodulizing of Iron Ores.

Field trips include visits to heavy media and cyclone plants, sintering operations, and taconite projects. Various mining operations employing belt conveyors, trucks, draglines, and fusion piercing will also be scheduled.

Registration fee will be $4.00 for members and $6.00 for non-members. Students will be admitted as guests. Fees should be submitted at time of registration, which closes August 31. Registration can be completed through E. C. Herkenhoff, Pickands, Mather Co., Hibbing, Minn.

Student Conclave Success Despite Snow

Heavy snow failed to stop the Second Annual Joint Meeting of the St. Louis Section and Student Chapters at the Missouri School of Mines, Rolla, Mo. Eighty students and guests listened intently to four speakers who presented views on various levels of the minerals industry.

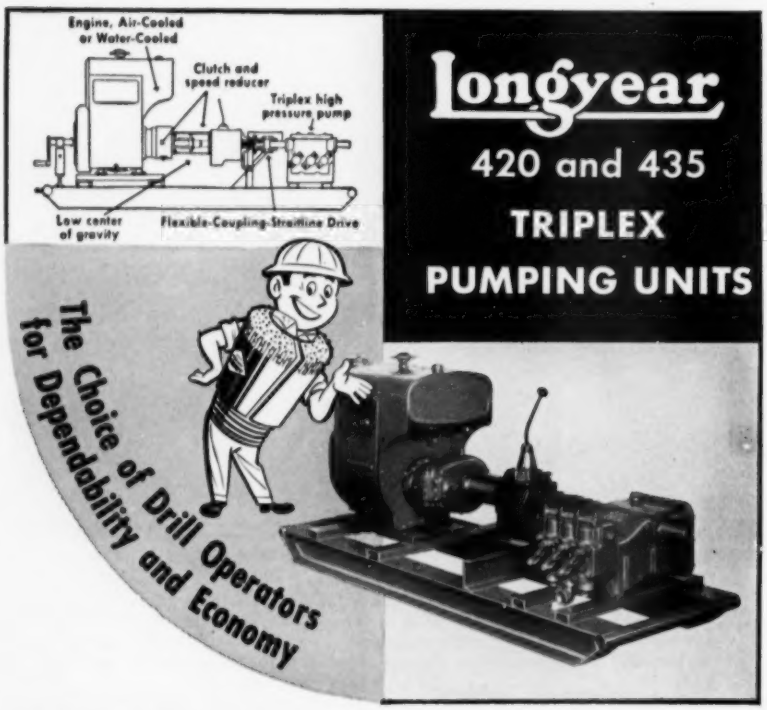
Day's activities started with registration followed by the welcoming address of Curtis L. Wilson, dean of the Missouri School of Mines. Following the luncheon, students heard Frank Lindeman, Jr., manager, Producing Department, Standard Oil and Gas Co., on employment with large companies.

L. H. Hart, discussing the foreign field, noted that students must bear in mind that they are guests in a country not their own. They have no immunity from the country's law and customs. O. W. Bilharz, president of the Bilharz Mining Co., viewed factors in working for small companies and private or individual enterprise.

Careers in government service were dealt with by LeRoy Williams, project engineer of the U. S. Geological Survey. The Rolla Ladies of the WAAIME carried on an afternoon program during the sessions.

Dinner that evening was held at the Edwin Long Hotel, in Rolla. Following dinner, *The Desloge Expedition Down the Colorado River*, was presented by Joseph Desloge, Jr. Mr. Desloge elaborated on the film and answered questions asked by the audience.

Dean C. L. Wilson, of the Missouri School of Mines, addresses students and guests at the Second Annual Joint Meeting of the St. Louis Section and Student Chapters. Fred J. Meek is on the left of Dean Wilson.



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A. Fletcher Addresses San Francisco Section

President Fletcher was the principal speaker at the April meeting of the San Francisco Local Section. He reported on Institute activities and gave an informative analysis of the effect of foreign metal imports on the domestic mining industry today. Legion of Honor Medals were presented to L. A. Levensaler and E. H. Nutter before a group of approximately 80 persons.

A luncheon was given by Chairman J. G. Huseby after which President Fletcher met with D. C. Jackling, a former President of AIME.

Nominating Committee Report Is Unanimous

S. S. Clarke, Chairman of the Nominating Committee for AIME Officers in 1954, states that the report of the Committee was made unanimous by mail vote following the meeting of the Committee in Los Angeles in February. The ticket was headed by Henry DeWitt Smith for President-Elect.

Board Approves Final AIME Budget for 1953

At its meeting in Tulsa, May 13, the Board of Directors approved the final budget for 1953. This indicated an income of $651,000, compared with actual income of $593,381 in 1952; and expenses of $608,100, compared with actual expenses of $575,315 in 1952. Of the 1952 surplus, $10,000 was returned to the Special Fund for Publications which had been drawn upon during the years of serious deficits, and of the anticipated surplus for 1953, $30,000 is earmarked for return to this reserve fund. The Fund will still remain less than half of what it was before it was tapped to meet the serious deficits of 1947 to 1949, amounting, in those three years, to $182,000.

AIME Represented In NBS Investigation

Dismissal of Dr. Allen V. Astin, director of the National Bureau of Standards, by Secretary Weeks, of the Dept. of Commerce, two or three months ago aroused a storm of protest from professional men. It appeared that the dismissal was caused by an adverse opinion of the Bureau on a certain additive to storage batteries, which the makers argued was a meritorious product. Most of the professional societies felt that the matter was of a political nature and that they should not sit in judgment. They agreed, however, to participate in a committee named, as Secretary Weeks expressed it, "to evaluate the present functions and operations of the Bureau of Standards in relation to the present national needs." Clyde Williams was named by the AIME as its representative on a seven-man committee headed by Dr. M. J. Kelly, president of the Bell Telephone Laboratories.

El Paso Regional Meeting Scheduled October 28 to November 2

Regional meeting of the AIME, scheduled for El Paso, Texas, October 28 to November 2, will take place against the backdrop of one of the biggest International Mining Days celebrations in the city's history.

Industrial Minerals Div., and Mining Geology are scheduling a full program of general sessions, group luncheons, banquets, technical meetings, and a suppliers party. One of the outstanding social events will be a ranchero breakfast. Several field trips are also on tap.

International Mining Days is sponsored by the mining committee of the El Paso Chamber of Commerce. Ben D. Roberts, general manager of the El Paso branch of American Smelting & Refining Co., is committee chairman. Mr. Roberts is also El Paso AIME Mining Section Chairman. More than 1000 persons are expected to the annual event, with the New Mexico Mining Association holding its annual meeting at El Paso during the celebration in addition to the planned AIME meeting.

Mining men from the U. S., Mexico, and Canada have already signified that they plan to be at El Paso, called the "sunshine playground of the Border." The Chamber of Commerce almost guarantees perfect weather for maximum enjoyment of the city's many recreational, educational, and cultural facilities. Golf, tennis, swimming, fishing, and other sports are to be had on almost any day of the year. Golf courses are closed an average of five days per year because of poor weather.

Spokesmen for El Paso claim it is the ideal convention city, offering magnificent meeting facilities and unmatched opportunities for relaxation. Intermingled with technical sessions will be field trips to the Carlsbad Caverns and to nearby potash mines. Old Mexico, near enough to use one's own car, awaits delegates attending the Regional Meeting. Ciudad Juarez is a short walk across the Santa Fe Street bridge.

Juarez is the scene of many bull fights, with its Plaza Del Toros crowded on any afternoon during the season.

Downtown El Paso presents a breathtaking vista from Scenic Drive along the face of Mt. Franklin. Juarez, just across the Rio Grande in Mexico, can be seen in the background. Native Americans with proper identification have no trouble in visiting Old Mexico.

Around the Sections

• Consulting Geologist Dorsey Hager spoke to the **Utah Section** on the *Oil Industry and the State of Utah.* At an earlier meeting John L. Chapman, chief of the Processing Branch, Atomic Energy Commission, Grand Junction, Colo., spoke on the uranium ore deposits in the Colorado Plateau and method of mining. A joint meeting with the Utah Industrial Safety Society and the American Society of Safety Engineers was planned for April. Kennecott Copper Corp.'s safety department presented the program.

• A lecture and demonstration on *Microwaves, and How They Work* was presented by Chuck Seavey of Pacific Telephone and Telegraph Co., at a meeting of the **Oregon Section** at the Mallory Hotel in Portland, Ore. A discussion of mining bills before the Oregon legislature followed. Lewis E. Scott, chief geologist of the Oregon State Highway Commission presented a program on *The Application of Geology to Highway Construction Problems,* at another meeting.

• The Hotel Cortez was the scene of two meetings of the **El Paso Metals Section.** M. Stanley Walker, chief engineer, Climax Molybdenum Co. gave an account of his firm's operations at Climax, Colo. Standard Oil Co., of Texas research engineers L. F. Bauer and L. T. Savage told of the new catalytic cracking unit at the Standard Oil refinery at El Paso, at another gathering.

• Movies of the eruption of Paracutin Volcano in the State of Michoacan, Mexico were shown by Alan Probert, assistant regional director, Region 9, of the U. S. Bureau of Mines at a meeting of the **Washington, D. C. Section.** William Foshag, official U. S. observer at the scene of the eruption, answered questions put by those attending the regular dinner meeting of the group.

Staff Changes Made in AIME Publications

J. V. BEALL

A. S. COHAN

John V. Beall, Manager of Publications of AIME and Editor of MINING ENGINEERING, has resigned to accept a position in the Raw Materials Dept. of the Atomic Energy Commission in New York. Mr. Beall had been with the Institute since 1948, starting as Assistant Editor of MINING AND METALLURGY. He became Editor of MINING ENGINEERING in 1949 when that magazine was started, and in 1950 was also appointed Eastern Secretary of the Mining Branch, a position he held until April 1952. He was made an Assistant Secretary of the Institute in 1951. Mr. Beall is a graduate of the School of Mines, Columbia University. He previously held positions at Idaho Maryland Mines, Grass Valley, Calif., and with Howe Sound at Holden, Wash. His new position will involve exploration work for the Atomic Energy Commission.

Alvin S. Cohan has been appointed Acting Manager of Publications to succeed Mr. Beall. Mr. Cohan graduated from Rensselaer Polytechnic Institute as a metallurgical engineer, and did some graduate work at New York University. He started with the Institute as Assistant Editor of JOURNAL OF METALS in 1950, after several years experience in industry. He became Editor of JOURNAL OF METALS in 1952, and will continue as Editor in addition to his new duties.

C. M. COOLEY

Charles M. Cooley, Secretary of the Mining Branch and Associate Editor of MINING ENGINEERING, has been appointed Acting Editor of that journal in addition to his Secretarial duties. Mr. Cooley came to the Institute from Climax Molybdenum Co. in 1951, where he was Assistant Chief Engineer. He became Associate Editor of MINING ENGINEERING and in 1952 was appointed Secretary of the Mining Branch. Mr. Cooley, a mining engineer, is a graduate of Texas Western College of the University of Texas at El Paso.

New Local Section

A new Local Section of the AIME has been recognized by the Executive Committee. It embraces the following counties of Texas: Collin, Dallas, Cook, Denton, Rockwall, and Grayson. The Section will be known as the Dallas Local Section, and its area was formerly included in that of the North Texas Section.

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Personals

James Robert Stewart won the 1953 Old Timers' Award, given annually to the University of Kentucky's outstanding senior in mining engineering. This award, a gold watch, was presented for the Old Timers' Club, by Defense Solid Fuels Administrator **Charles W. Connor.**

S. E. Watson has been retired after 26 years as assistant general manager with Andes Copper in Chile and is living in Berkeley, Calif.

Carl J. Christensen has resigned as dean of the College of Mines and Mineral Industries at the University of Utah.

Grosvenor C. Dyar has been appointed superintendent of the new Maxine Mine of Alabama By-Products Corp., Birmingham. He was formerly operating vice president of the Stith Coal Co.

Alvin Kaufman has resigned his position as research associate with the State Planning Board of Pennsylvania to accept a position as a sales engineer with the Hudson Coal Co.

ALBERT J. PHILLIPS

Albert J. Phillips, director of American Smelting & Refining Co.'s research department, Plainfield, N. J., has been made a vice president. Mr. Phillips is a former director of AIME. There have been several other important changes on ASARCO's roster. **Clement P. Pollock** has been appointed exploration manager. **L. H. Hart,** recently resident engineer, is chief geologist. **R. M. Belliveau** has been named resident engineer. Vice President **R. F. Goodwin** has a new assistant, **D. J. Pope.** Mr. Pope was general manager, Western Mining Department. All these men have their headquarters in New York. **J. E. Berg** is now general manager, Northwest Mining Department at Wallace, Idaho. **F. V. Richard** has advanced from manager of operations to manager of Western Mining Department in Salt Lake City. **Ward C. Ball** is general superintendent of Tri-State Properties with headquarters at Baxter Springs, Kansas.

EDWARD STEIDLE

Edward Steidle, dean of the School of Mineral Industries, Pennsylvania State College, was honored by a testimonial dinner given on May 2 for his 25 years of inspiring leadership. He was presented with a scroll and a gold watch by the students. Speakers were Elburt F. Osborn, associate dean who becomes dean on July 1, and Lewis E. Young, consulting engineer. Among those attending were Edgar C. Weichel, vice president, Hudson Coal Co., C. M. Cooley, AIME Mining Branch Secretary, George H. Deike, president, Mine Safety Appliances Co., E. H. Robie, secretary of AIME, and David M. Fleming, president Mineral Industries Student Council. John M. Ruffner was chairman of the Student Banquet Committee and John D. Ridge, Jr. was chairman of the faculty committee. Shown above is a portion of the portrait of the dean, painted by Malcolm S. Parcell, and presented to the school by the faculty and alumni.

When Edward Steidle was appointed dean of the School of Mineral Industries 25 years ago it was then housed in a wooden shack with a tar paper roof. Today its buildings have an enrollment five times as large and a staff fifteen times as large. Its research has grown from nothing to 100 approved projects. Under the dean has been organized the only mineral industries art gallery in the world. Graduates of the school are scattered from the frozen coal-fields of Spitsbergen to the submarine mines of Chile.

Martin Meyer has been appointed general sales manager of Sauerman Bros., Chicago, occupying the position held by the late Dwight D. Guilfoil. *(See OBITUARIES p. 632)*

P. J. Shenon stopped in at AIME headquarters while enroute to British East Africa. Mr. Shenon, who was recently nominated to be a director of the Institute, is a consulting geologist with R. P. Full in Salt Lake City.

H. P. Dickey, formerly with Kennco Explorations in Montreal, is with Dominion Wabana Ore Ltd. in Newfoundland.

E. K. Miller has been advanced to vice president in charge of production, of Jones & Laughlin Steel Corp., Pittsburgh.

J. B. Haffner, vice president and general manager of Bunker Hill & Sullivan Mining & Concentration Co., Kellogg, Idaho, has been elected president of the Lead Industries Association.

F. L. McDonald has left Kwakwani, British Guiana and is with American Cyanamid Co., Brewster, Fla.

Eugene F. Rossi has been assigned to Allis-Chalmers processing machinery department in Milwaukee.

ROBERT H. PEARSON

Robert H. Pearson, formerly vice president of Gardner-Denver Co., is manager of Air Rentals, Inc., a newly formed organization in Denver, specializing in mining and construction equipment and supplies.

S. Power Warren has completed 9 months experimental work at the Colorado School of Mines Research Foundation on carnotite ores. He will spend several months in New England supervising the installation of a cyanide plant to recover gold from factory wastes. His address will be Hotel Bond, Hartford, Conn.

C. Alves da Silva, professor of engineering at San Juan, has been appointed as director of the Institute of Mining Investigation at the University of Cuyo in Argentina.

William G. Wood is with Anaconda Copper Mining Co., Butte, Mont. He was formerly with E. J. Longyear Co. in Minneapolis.

Horace Y. Bassett, since 1947 vice president and general manager of the Wolverine Tube Div. of Calumet & Hecla, has been transferred from Detroit to Chicago as vice president of operations of Calumet & Hecla.

Jack McK. Pardee is working on the Cuajone Development Project for Cerro de Pasco Corp. in Moquegua, Peru.

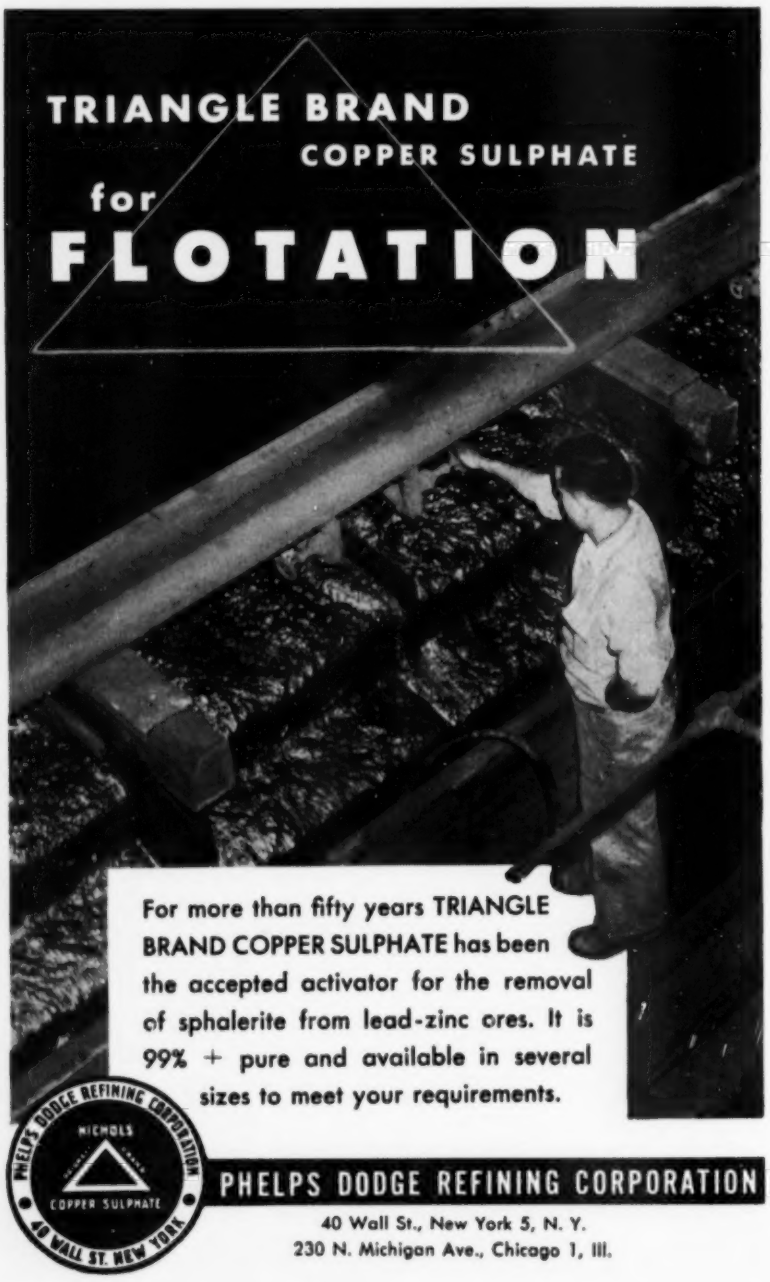
C. R. Hilton, after 20 years with Mount Isa Mines Ltd. in Queensland, Australia, has resigned as general manager and director to return to his home in Oakland, Calif.

C. H. Rieman has been promoted to sales manager of the Mining and Contracting Div. of Gardner-Denver. **J. A. Caverly** has been made sales supervisor of the Mining Div.

Lee Bilheimer, recently with St. Joseph Lead Co., is with Empire Star Mines Co., Grass Valley, Calif.

Theodore T. Uhle has accepted a position as geologist with Mountain Geophysical Co., Casper, Wyo.

Arthur M. Ferenz has left Wyandotte Chemicals Corp. in Michigan to go with Carl A. Bays & Associates, Urbana, Ill.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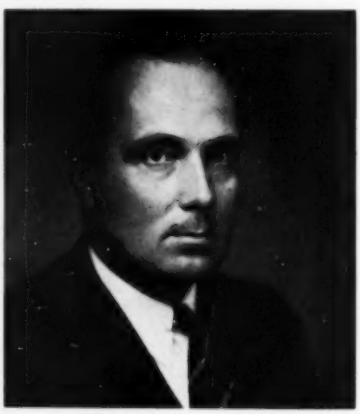
D. N. GRIFFIN

D. N. Griffin is vice president of Deister Concentrator Co., Fort Wayne, Ind. **S. A. Stone** replaces him as chief engineer. **R. T. Bliss** has been made vice president in charge of sales and service for Deister's Anthracite District, Nesquehoning, Pa.

Robert Sanford has returned to Amarillo, Texas, to become special assistant to **Dr. C. W. Seibel,** regional director, Region IV, Bureau of Mines. Mr. Sanford, who inaugurated the first Point-Four program in a foreign country, has been in Asia. In India he helped start a lignite-coal development, in Nepal he helped put some ancient metal mines back into profitable production, and in Afghanistan the coal mining project he started resulted in more production per 40 miners than 150 had produced previously.



RICHARD L. BOWDITCH

Richard L. Bowditch, president of C. H. Sprague & Son Co., and president of the Sprague Steamship Co., both of Boston, and now president of the U. S. Chamber of Commerce, has been an AIME member since 1925. He earned his first money as a trapper boy in a Logan County, West Virginia coal mine 30 years ago.

William Brill is now director of engineering for Colorado Fuel & Iron Corp., Pueblo, Colo.

ALBERT E. FORSTER

Albert E. Forster has been elected president of Hercules Powder Co., Wilmington, Dela. Mr. Forster, formerly vice president, spent his vacations while a mining engineering student at Stanford working in a copper mine and surveying for a cement company. He joined Hercules in 1925 as an explosive engineer and returned to the company after working four years in Brazil for a power company.

Josiah Thomas, former general manager of the Cia. Minera Unificada del Cerro de Potosi, Bolivia, is in Lima, Peru, with Ventures Ltd. as manager of their Chavin Mines Corp.

Stanley M. Walker, accepting transfer from DMPA, has gone to Kathmandu to act as technical advisor on mining to the Nepalese Government. He expects to be in Nepal two years.

JOSEPH L. WALKER

Joseph L. Walker has joined Heyl & Patterson in Pittsburgh as contracting engineer. For the past 3 years he has been in charge of Coal Preparation Extensions Services at Penn. State.

L. J. Bechaud, Jr., formerly with M. A. Hanna Co., Hibbing, Minn., is now chief research metallurgist in the laboratory for Newmont Mining Co. at the property of Empire Star Mines, Grass Valley, Calif.

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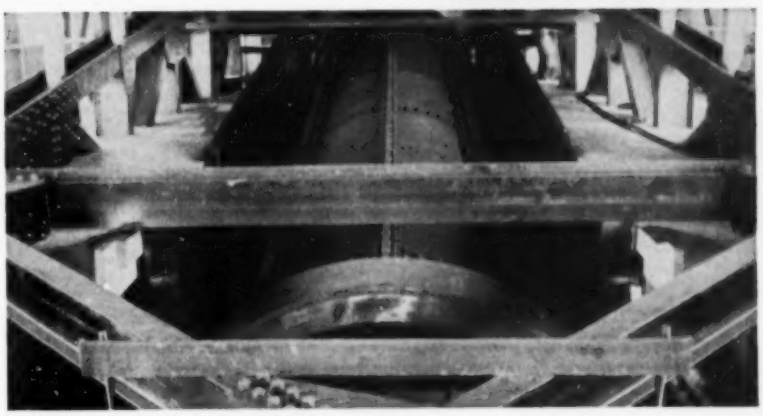

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Obituaries

Firmin V. Desloge (Member 1903) died May 18, 1952. Mr. Desloge was president of the Smokey Oil Co., St. Louis. He prepared for his mining career at MIT, graduating in 1902. For many years Mr. Desloge was general superintendent of Desloge Consolidated Lead Co. in Missouri and became vice president in 1912. He was later president of the Desloge Investment Co. in St. Louis.

Dwight D. Guilfoil, 66, vice president and general sales manager of Sauerman Bros. Inc., died of a heart attack in his home in Chicago on May 3, 1953. He had been with Sauerman Bros. since 1913, except for a period during World War I, when he served with the 108th Engineers in France, coming out of the war with the rank of major. Mr. Guilfoil had been active in the affairs of the National Sand and Gravel Assn. and other trade associations. He was a long-time member of the Chicago Engineers' Club.

Harold Tourtel Herivel (Member 1948) died Nov. 17, 1952. He was metallurgist with the Phelps Dodge Corp., Morenci, Ariz. Born in England, he studied at the Missouri School of Mines and was a lieutenant with the Engineers during World War I. Before working with the Phelps Dodge Corp., he spent more than 20 years with the Esperanza Mining Co. in Mexico.

Albert W. Johnston (Member 1905) died. Mr. Johnston was president of American Nickel Works and vice president of Orford Copper Co. After studying at Brooklyn Polytechnic Institute and Wesleyan, he worked as a metallurgist in a dental manufacturing laboratory, later becoming interested in gold and silver mining in Canada. In recent years Mr. Johnston had made his home in Greenwich, Conn. where he was a Member of the State War Council.

Albert J. Jones (Member 1944) died Dec. 1, 1952. He was a consulting mining engineer and petroleum geologist. Mr. Jones began as an apprentice assayer in Chihuahua, Mexico where he studied at Palmore College. After graduating from the University of Texas he returned to Mexico to work for Candelaria Mining Co. More recently Mr. Jones was employed as a resident geologist for the Humble Oil Co., the Wilshire Oil Co., and as a supervising engineer with the RFC.

Charles B. Lessner (Member 1907) died. Mr. Lessner was born in London, studied chemistry and metallurgy at Birbeck and Kings' Colleges. For a short period he was an assayer on the Gold Coast, West Africa. In 1905 Mr. Lessner went to Spain where he worked as a metallurgical chemist and soon became manager of the Carrill Works. He was a Life Member of AIME.

Alexandre Lheraud (Member 1918) died December 1951. Mr. Lheraud was born and educated in France. He spent many years in Spain working as chief engineer in coal, lead, and zinc mines before becoming general manager of the Societa Mineraria e Metallurgical di Pertusola in Genoa, Italy.

Poole Maynard (Member 1941) died Aug. 22, 1952. Mr. Maynard was a consulting geologist and technologist with more than 100 geological bulletins and technical papers to his credit. After receiving his Ph.D. from John Hopkins in 1909, Mr. Maynard became assistant State Geologist of Georgia, and much of his later work was done in that state. He originated patents for manufacturing heavy clay vitrified products from slag and

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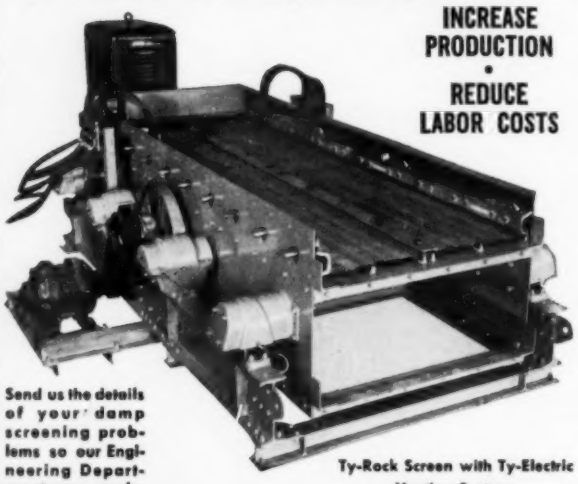

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clay, and was among the first to recover potash commercially from shales and to locate bentonites and roofing slates in Georgia. Among his many affiliations he was listed as a Fellow of the Geol. Soc. of Am., AAAS, and the Paleontological Soc.

Frank G. McClure (Member 1948) died March 2, 1953. Mr. McClure was born in Indiana, and after his graduation from the University of Arizona in 1917 worked for Phelps Dodge Corp., Bisbee, Ariz. For 7 years he was foreman at the Chief Consolidated Min. Co., Eureka, Utah, and later foreman on construction for Six Companies, Inc., Boulder City, Nev. Since 1936 Mr. McClure had been a mining engineer for Miami Copper Co., Miami, Ariz.

Joseph S. Peterson (Member 1927) died March 13, 1953. Mr. Peterson was vice president and assistant general manager of the Benguet Consolidated Mining Co. in the Philippines. He was born in Minnesota and graduated from the State University in 1909 with an E.M. degree. For many years he was assistant manager of the Tomboy Gold Mine in Colorado, and later mine supervisor for the Cia. de Real del Monte y Pachuca in Mexico.

Earl G. Schulz (Member 1935). Mr. Schulz was killed in an automobile accident on his way back to McGill, Nev. He had been on temporary assignment as consultant engineer to the Murgul Copper Mines in Turkey. Mr. Schulz was on leave of absence from the Kennecott Copper Corp. in McGill where he was smelter general foreman. He studied at Oregon State College and graduated in 1935 from the University of Alaska. While in Alaska he worked as a draftsman, rodman and surveyor for the Fairbanks Exploration Co.

NECROLOGY

Date Elected		Date of Death
1949	Kelber Bordez	Unknown
1916	Hugh Robert Edwards	Feb. 23, 1953
1934	Gerald B. Gould	Mar. 20, 1953
1950	Norman C. Prudent	Unknown
1908	Bertram D. Quarrie	Feb. 15, 1953
1936	Robert C. Ried	Mar. 27, 1953
1905	H. St. J. Somerset	Sept. 20, 1952
1906	M. W. Summerhayes	April 1953

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on Feb. 28, 1953 was 18,262; in addition 2,008 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; Philip D. Wilson, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, George N. Lutjen, E. A. Prentis, Sidney Rolle, John T. Sherman, Frank T. Sisco, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Alabama
Birmingham—Hudson, Homer B., Jr. (M)
Birmingham—Joyce, John H. (A)

Arkansas
Malvern—Higgins, Albert J. (R. C/S—S-J)

Arizona
Inspiration—Carlson, Donald O. (C/S—A-M)
Winslow—Cooper, Donald K. (R. C/S—S-J)

California
Arcadia—Perrine, Clifford V. (M)
Los Angeles—Loevenstein, Hirsch (M)
Redding—Murphy, John X. (R. C/S—J-M)
Riverside—Weishaupl, Franklin J. (R. C/S—S-M)
San Carlos—Craig, George H. (M)
San Francisco—Goodwin, Joseph G. (R. C/S—S-M)

Colorado
Climax—Gregory, William J. (A)
Durango—Simpson, Robert E. (C/S—J-M)
Gilman—Eichmeyer, Helmut (J)
Gilman—Hanners, Jerome T. (J)
Leadville—McDaniel, Joseph P. (C/S—S-J)
Pueblo—Blalock, Clovis C. (C/S—J-M)
Silverton—Chase, Edward T. (M)

Connecticut
Westport—Priestley, Robert J. (J)
Wilton—Thompson, Robert B. (M)

Florida
Eglin Air Force Base—Enochs, David J. (J)
Lakeland—Caldwell, Robert A. (A)
Lakeland—Chitty, Thomas C. (A)
Mulberry—Smith, Matthew T. (M)
Plant City—Sawitzke, Edward A. (R. M)
Tallahassee—Calver, James L. (M)

Georgia
Sandersville—Kingman, William W. (R. M)

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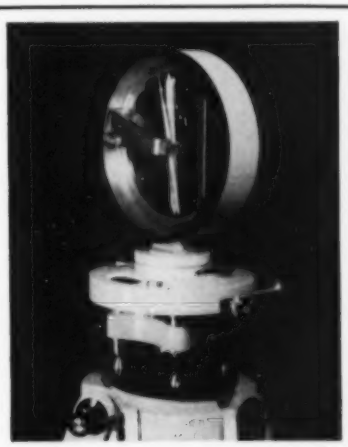
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Illinois
Chicago—Baker, John H. (A)
Galesburg—Rose, Colin G. (R. C/S—S-M)

Kansas
Pittsburg—Citron, Elmer H. (M)

Massachusetts
Cambridge—Charles, William D. (C/S—S-J)
Chestnut Hill—Mitchell, John (M)

Michigan
Calumet—Spencer, R. Robbins (R. C/S—S-M)
Champion—Smith, Lawrence E. (M)
Ishpeming—Nicolson, John A. (M)

Minnesota
Coleraine—Pearson, Ronald B. (M)
Hibbing—Mayer, Christian J. (M)

Montana
Anaconda—Mergerth, Frederic H. (J)
Butte—Riethmeier, Walter C. (C/S—S-J)
Libby—Redmon, Donald E. (C/S—A-M)

New Jersey
Maywood—Hook, William D. (A)
Sparta—Swartz, Ralph R. (R. C/S—S-J)

New York
New York—Brassert, James E. (J)
Pelham Manor—Weldon, Joseph M. (M)
Yonkers—Maxwell, Henry W. (J)

Oregon
Granite—Jackson, James P. (M)

Pennsylvania
Allentown—Uhle, David J. (M)
Altoona—Holtzinger, John E., Jr. (J)
Bellefonte—Mensing, Henry E. (C/S—S-J)
Carlisle—Ahl, George W., Jr. (A)
Easton—Tone, Donald R. (R. C/S—S-J)
Jacobs Creek—Simkovich, George (C/S—S-J)
Pottsville—Svender, Russell L. (R. M)

Tennessee
Jefferson City—Ferguson, Herman W. (M)

Texas
Bandera—Thompson, Rumsey G. (M)
Blanket—Ryan, Daniel P. (R. C/S—J-M)

Utah
Heber City—Anderson, Don C. (J)
Salt Lake City—Bole, Joe A. (A)
Salt Lake City—Costas, Tom P. (A)

Vermont
Barre—Gillette, Robert S. (M)
Proctor—Reisaig, Barton N. (M)

Virginia
Arlington—Chandler, Henry P. (M)
Falls Church—Graham, Jack B. (M)

West Virginia
Bluefield—Lane, Robert S. (R. C/S—A-M)

Alaska
Anchorage—Reeve, Robert C. (A)

Australia
Radium Hill—Harris, Leonard (J)

Brazil
Macapa, T. F. do Amapa—Sydenstricker, Daniel G. (A)

Canada
Alberta, Edmonton—McCreedy, Hedley H. (J)
B.C., Tulsequah—Christensen, Arthur K. (J)
B.C., Tulsequah—Smith, Derrick B. (M)
Ontario, Copper Cliff—Kossatz, Mason C. (J)
Ontario, Ottawa—Bickford, Kenneth F. (R. C/S—J-M)
Quebec, Dorval—Weymark, William J. (A-M)
Quebec, Town of Mount Royal—Moss, Albert E. (M)
Saskatchewan, Uranium City—LaPrairie, Leon F. (J)

Peru
Lima—Nevin, Norman M. (M)
Morococha—Maas, Robbert (A)
Pacasmayo—Alvarez-Calderon R., Guillermo (M)

Philippines
Dagupan-City—Bacani, Jose M. (R. C/S—S-M)

Portugal
Beira Baixa—Ferro, Manuel N. (J)

Sweden
Malmberget—Fagerberg, Bengt Georg (R. C/S—S-M)
Saltsjoe-Duvnes—Thomaeus, Ivar G. R. (M)

Venezuela
San Felix, Estado Bolivar—Shingler, William H. (M)

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Coming Events

June 3-7, Chemical Institute of Canada, Windsor, Ont.

June 12-13, Spring Meeting, Central Appalachian Section, AIME, Beecher Hotel, Somerset, Ky.

June 16-19, Exposition of American Welding Society, Shamrock Hotel, Houston, Texas.

June 16-19, Materials Conference held concurrently with First Exposition of Basic Materials, Hotel Roosevelt, New York.

June 29, Lima, Peru Section Cocktail-Dinner-Dance commemorating First Anniversary, Lima Country Club, Lima. All AIME members welcome.

July 13-16, Golden Jubilee of the Idaho Mining Assn., Sun Valley, Idaho.

Aug. 31-Sept. 2, Minerals Beneficiation Division, Hibbing, Minn.

Sept. 8-13, Joint Meeting Industrial Minerals Division, AIME, Keltic Lodge, Ingonish, Nova Scotia.

Sept. 11, St. Louis Lead Belt Meeting, Tour of St. Joseph Mines and Mills, St. Louis.

Sept. 21-23, American Mining Congress Mineral Mining Convention, Olympic Hotel, Seattle.

Oct. 1-2, Regional Meeting, Pacific Petroleum Chapter, Ambassador Hotel, Los Angeles.

Oct. 8-9, Ninth National Conference on Industrial Hydraulics, Hotel Sheraton, Chicago.

Oct. 15-17, Second Annual Clay Minerals Meeting, University of Missouri, Columbia, Mo.

Oct. 18-21, Petroleum Branch Fall Meeting, Baker and Adolphus Hotels, San Antonio.

Oct. 19-21, Institute of Metals Division, Fall Meeting, Hotel Allerton, Cleveland.

Oct. 28-31, AIME, El Paso Meeting, in cooperation with International Mining Days, Hotel Paso Del Norte, El Paso.

Oct. 29-30, AIME, ASME Fuels Conference, Conrad Hilton Hotel, Chicago.

Oct. 29-31, Annual Meeting of National Council of State Board of Engineering Examiners, Plaza Hotel, San Antonio.

Dec. 3-5, Electric Furnace Steel Conference, Netherland Plaza Hotel, Cincinnati.

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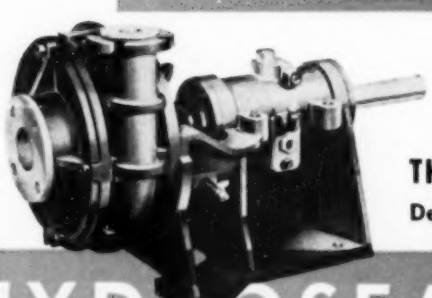

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